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ABSTRACT

This exploratory study was aimed at uncovering childrens' beliefs and ideas about the human circulatory system. Thirty-two subjects, aged 7 to 14 years, were interviewed using a modification of Piaget's clinical method. The data were analyzed by developing a conceptual inventory of beliefs for each of five research questions. It was found that the interview methodology was effective in ascertaining these belief structures. Many children were found to possess similar beliefs about certain aspects of the circulatory system. Developmental trends were also evident from the data collected. It was also found that many of the beliefs from the study paralleled the ancient scientific ideas about this system. It is felt that the beliefs uncovered in the study will aid the educational community by providing insight into some of the "typical" ideas that children bring to the classroom. This study is organized into five chapters with five appendices containing supporting documentation. These include an exemplary transcript from a student interview, diagrams of the heart and circulatory system from the interview, and a list of nine belief summaries derived from the exemplary student interview. (Author/JN)

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EDUCATIONAL RESEARCH INSTITUTE OF BRITISH COLUMBIA

Report No. 82:16

CHILDRENS' BELIEFS ABOUT THE HUMAN CIRCULATORY SYSTEM: AN AID FOR TEACHERS REGARDING THE ROLE INTUITIVE BELIEFS PLAY IN THE DEVELOPMENT OF FORMAL CONCEPTS IN 7-14 YEAR OLDS

Robin W. Catherall

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This exploratory study was aimed at uncovering childrens' beliefs and ideas about the human circulatory system. Thirty-two subjects, aged from 7 to 14 years, were interviewed using a modification of Piaget's Clinical Method. The data were analysed by developing a "conceptual inventory" of beliefs for each of five research questions. It was found that the interview methodology was effective in ascertaining these belief structures. Many children were found to possess similar beliefs about certain aspects of the circulatory system. Developmental trends were also evident from the data collected. It was found that many of the beliefs from this study paralleled the ancient scientific ideas about this system. It is felt that the beliefs uncovered in this study will aid the educational community by providing an insight into some of the "typical" ideas that children bring to the classroom.

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CHAPTER ONE

THE PROBLEM

1.00 Introduction

The focus of science education curricula has changed a great deal over the past fifty years. It has evolved from a "subject-centered" curricula where the materials and teaching strategies are established at a time prior to classroom implementation, to a "child-centered" approach where decisions about instruction are related to some form of psychological theory.

Shulman and Tamir (1973) have identified the need for research which directs itself towards the establishment of a type of cognitive psychology focused on those concepts felt to be important in the field of science education.

> "...such science-relevant basic research would be on a topic like the cognitive development of science-relevant concepts in young children....The purpose would be to identify some general normal expectancies for the evolution of particular concepts around which curriculum developers and program writers could plan their creative endeavors....The importance would be to provide general maps that would be useful for the activities of the curriculum developers."

One area of recent educational interest in cognitive psychology has been in the role that intuitive beliefs play in the development of formal concepts. A number of investigations have suggested the importance of these early beliefs as they are evolved into mature concepts (Ausubel,1968; Driver and Easley,1978; Erickson,1980; Kargbo, Hobbs and Erickson,1980). It has been suggested that the knowledge of these beliefs could benefit the educational

community by raising the level of awareness of teachers and curriculum developers with respect to some of the many perspectives that students bring to the classroom.

This study focuses on the child's beliefs about the human circulatory system. This topic was chosen for five reasons: 1) This has been the source of a great deal of attention today with a shifting societal emphasis towards health and fitness. As a result, it is popular opinion that children should know more about their bodies. 2) This is a topic to which everyone is exposed, both before and after formal instruction. 3) Most school systems include this as part of their curriculum, either at the intermediate level or during the high school program. 4) Some curricula implicitly assume that children have a basic understanding of the body with respect to its structure and function. 5) To date there has not been any research which has investigated this topic.

The researcher has chosen to use an adaptation of Piaget's Clinical Method as a means to collect these beliefs. There were no apriori predictions about the nature of the child's belief structures, however, the basic assumption is that all children possess some preconceived theory or belief about the form and function of the circulatory system. Consequently, this study is descriptive and exploratory in nature. There was no formal testing of research hypotheses. The researcher is attempting only to identify the extent and the nature of the child's beliefs about the circulatory system. It is hoped that the

discussion of the findings of this study will serve to generate more specific hypotheses for future research.

1.10 The Problem

The purpose of this study was to investigate the nature of children's beliefs in the following three research areas.

(1) What is the function of the heart?

(2) What are the paths and methods of blood circulation?

(3) What are the functions of the blood?

(3a) How is the blood related to the respiratory system?

(3b) How is the blood related to the digestive system?

These three research questions are further reduced to more specific questions which were addressed to each child during the interview. These specific interview questions are indicated in Chapter Three.

The investigator was interested in determining the ideas that children have about: (1) the functions of the various circulatory structures and organs, and (2) how these structures and organs are interrelated to produce an overall framework for the functioning of the circulatory system.

The beliefs will be analysed to determine if there are any trends or consistencies which might coincide with the development or the sex of children as they are observed

from grades two through eight.

1.20 Methods of Study.

1.21 Data Collection

The researcher has chosen to use a modified version of Piaget's Clinical Interview Technique. A set of questions was prepared to ensure that all aspects of the three problem areas were explored with each child. Further probing of the students' initial responses were carried out to determine the degree to which the child was "romanticizing" or was subject to suggestion by the interviewer. In contrast to most formal Piagetian-type interviews, there were no concrete tasks which required the child to predict the outcome of some sort of experiment or transformation. However, the interviews did involve a few simple activities which served only to facilitate the flow of the discussion.

It was felt that the Piagetian Clinical Method was most appropriate for this study because it allowed for the greatest latitude in the subject's description. In addition, the practitioner was free to explore the "natural inclinations" and "spontaneous interests" of the child. (Piaget, 1929)

Attempts were made to create a discussion-type format instead of a direct question-answer interview. If a child responded to a particular question so that subsequent questions were also addressed, then these latter questions were dropped from the protocol.

1.22 The Subjects

Because of the exploratory nature of this study, the generalizability of the results was not a major issue. For this reason the sample size was quite small. Thirty-two subjects, all from schools in the Richmond School District of British Columbia were interviewed.

The data were analysed with respect to trends which might occur in both the chronological development of the child and the sex of the child. For these reasons, the sample included eight students each from grades 2, 4, 6, and 8. Equal numbers of each sex were included in this sample.

The two schools which participated in this study were located in an urban setting in the Greater Vancouver District. The students attending these schools represented a "normal" mixture of socioeconomic backgrounds.

The 32 subjects chosen for this study were a "sample of convenience" where each student was randomly selected from a group of consenting students.

1.30 Educational Significance of the Study

According to Piaget, the process of learning in the child involves a continual interaction with the environment. By becoming actively involved with objects or properties of objects in their physical and social world, the child gradually constructs a set of mental structures or schemes which they use to make sense out of their world. The evolution of a particular concept, which would be one of the

components of these schemes, is thought to go through a series of progressive adaptations (through this interaction process) until the student or adult no longer sees any need to alter this concept.

Most young children will have experienced various aspects of their internal body. These might include: feeling their heartbeat, feeling or hearing their pulse, loosing blood at the site of an injury, breathing in air, or ingesting foodstuffs. As a result, these children should have developed various intuitive explanations or hypotheses to explain these phenomenon in their bodies. Most of these beliefs would have been formed in the absence of formal school instruction. As the child matures, these become "assimilated" and "accomodated" into new conceptions as a result of experiencing further stimuli or by receiving some type of external explanation.

When children receive formal instruction in the classroom, they may not necessarily accept new explanations which are presented to them. Instead they might only assimilate this new instructional information to their former beliefs and ideas. As a result, it may be possible to detect traces of these intuitive beliefs at a time following formal instruction. It has been said that these early beliefs are "amazingly tenacious and resistant to extinction" as they are incorporated into the maturation and development of a concept. (Ausubel,1968).

Obtaining knowledge of these intuitive ideas would be of great assistance to the educational community. By

determining the nature of these beliefs, it may be possible to create special instructional strategies which will promote the development of desired concepts in an optimal direction.

They may aid curriculum developers to produce specific materials which emphasize special strategies for certain misconceptions. Also, it may help to decide the appropriate ages for the introduction of specific concepts in the curricula.

Teachers would benefit from the knowledge of these belief structures by having a better interpretive understanding when presenting these concepts, and also by being able to select appropriate curricula for their students.

1.40 Limitations of the Study

In this study it is assumed that the Clinical Interview Method is a useful instrument which can be used to attain the child's intuitive ideas about the human circulatory system. However, there are limitations as to the validity of this technique in determining the correct interpretation of the child's belief structure. Two methods which might be employed to validify the final belief summaries include: (1) submitting the data to other researchers for their analyses, and later cross-checking these with the present findings, and (2) administering an objective paper and pencil test to confirm the analysis of this investigation.

This study has a sample size of 32 individuals. Such a small number of subjects will certainly pose a restriction as to the generalizability of any findings. Consequently, one must assume that the beliefs uncovered in this investigation are typical only to the subjects interviewed. This external validity can only be increased if similiar research with larger, more representative groups of students is conducted in the future.

The researcher assumes that each of the subjects has a similiar background with respect to their health education in this area. However, differences will likely exist between subjects, both in terms of their instruction from home and from school. Only detailed backgound research will reveal this degree of sample homogeneity.

CHAPTER TWO

LITERATURE REVIEW

2.00 Introduction

The literature review for this study will direct itself to four principal areas:

(1) The psychological context of the study.

(2) The history of the scientific conception of the heart and the circulatory system.

(3) Current health education in Canada.

(4) The pedagogical context of the study.

2.10 Psychological Context of the Study

No study of the development of a concept in science would be complete without first considering some of the major theories of intellectual development.

Perhaps the most famous developmental psychologist of recent times has been Jean Piaget. The work of this man has had a profound influence upon both education and child psychology.

Piaget believed that to fully comprehend human knowledge, one would first have to study the formation and evolution of the individual's cognitive growth. For this reason, he devoted the initial part of his career to the psychological study of the child's understanding of reality. His findings were published in two well-acclaimed books

(1929 and 1930). With the progression of his work in this area, Piaget became increasingly aware of the differences in thought processes between the child and the adult. This prompted him to produce a theory which would account for the development of human intelligence.

Piaget states that from the earliest years of life, individuals are actively engaged in a continual interaction with the immediate surroundings of their environment. This active interaction involves two functions which affect intelligence: organization and adaptation. The term "organization" refers to the tendency to organize thought processes into coherent mental structures or schemes. Piaget uses "adaptation" to indicate the tendency of the organism to adapt to the environment. This is said to involve two complementary processes: assimilation and accomodation. Ginsburg and Opper provide a concise definition for these two terms.

> On the one hand the person incorporates or assimilates features of external reality into his own psychological structures; on the other hand he modifies or accomodates his psychological structures to meet the pressures of the environment..... Moreover, these processes are simultaneously present in every act. (Ginsburg and Opper,1969, p.18 & 19)

According to Piaget's theory, cognitive development is influenced by four factors: heredity, social transmission, equilibration, and experience. Piaget uses the term "heredity" to refer to the inherited physiological structures which are necessary for psychological

development. "Social transmission" on the other hand, refers to the social interaction with other people. Such interaction may be either verbal or physical.

Piaget defines "equilibration" as the state which brings psychological stability to the world (Ginsburg & Opper, 1969). When faced with a cognitive disturbance such as trying to understand something, the individual will try to assimilate this experience into a mental scheme and he will also try to accomodate his present mental scheme to comply with the experience.

Piaget (1964) indicates that contact with objects in the environment can produce two types of "mental experience". He labels "physical experience" as that knowledge which is drawn directly from the properties of objects. The second type of experience is "logical-mathematical experience". This is said to result in knowledge which is drawn not from the objects themselves, but from the properties of the actions carried out on the objects.

Perhaps the most signifigant factor for the present study is that of physical experience. The research questions posed in this study are based upon an assumption that when young children try to understand a novel situation, they are faced with a cognitive disturbance. In order to make sense of this situation or experience, the child "adapts" to the disturbance through assimilation and accomodation. In so doing, simple intuitive beliefs or

theories are developed.

In order to account for the vast differences in mental capacities between the child and the adult, Piaget theorized that the child progresses through a series of qualitatively different psychological structures. Three stages of development have been identified: the sensorimotor stage, the concrete operational stage, and the formal operational stage. All children are said to proceed through the same stages in the same order, but at different rates of development.

The present study does not attempt to correlate the child's belief structures to the preceeding three stages. Rather, Piaget's theoretical description of the child's construction of knowledge serves as a general framework for this study.

Another psychologist whose theory of learning has had some influence on educational psychology is D. Ausubel. According to his theory, "new conceptual material can only be learned if it is related in some way to the existing cognitive structure of the individual" (Ausubel 1968). The final learned product, then, would be a modification of the input and of the existing cognitive structure.

Van Kirk summarizes the gist of Ausubel's theory:

> ...meaningful learning, on the other hand, occurs when new material is anchored to existing concepts in the cognitive structure (subsubers) through an interactive process called subsumption. As new material is subsumed, it is slightly modified, as

> is the existing knowledge to which it is being anchored. As meaningful learning occurs, then, subsuming concepts are necessarily progressively differentiated. When apparently contradictory new knowledge is to be learned, the process of integrative reconciliation of the contradictory elements, under a more inclusive subsumer, may occur.... (Van Kirk, 1978, pp.2 & 3)

Wollman (1978) points out many similiarities between Ausubel and Piaget in their ideas on the development of concepts. Instead of "assimilating" and "accomodating" in the Piagetian sense, new concepts are said to be "subsumed" with existing cognitive structures. Similarly, "progressive differentiation" and "integrative reconciliation" are also said to be synonymous to Piaget's "assimilation and accomodation of mental schemes".

The present study assumes that children develop mental concepts according to the theories of Piaget and Ausubel as described above. Consequently, it is believed that children develop their intuitive ideas by actively experiencing stimuli from the environment. It is hoped that the theories of these two psychologists can be implemented to allow for an interpretation of the belief structures which are uncovered in this study. Thus it may be possible to account for the origins of these beliefs, as well as to trace the development of these typical beliefs as children mature. In addition, it is hoped that these two theories can aid the educational community to further the evolution of these belief structures along desired lines of development.

2.20 The History of the Scientific Conception of the Heart and the Circulatory System

According to Piaget's theory of "genetic epistemology" (Piaget 1972), the historical development of knowledge has many parallels with the intellectual development of knowledge in the child. For this reason, he suggests that "the study of this development at both levels might yield insight into the most mature (or at least the latest) forms of collective and individual knowledge". (Ginsburg & Opper,1969)

The following discussion will be directed towards a brief history of the scientific conception of the heart and the circulatory system.

Throughout history, the discovery of new scientific ideas has been guided by social, academic, and technological factors. Our present conception of the heart and the circulatory system has resulted from a continual evolution of these historical theories and ideas. This progression of ideas has been documented in the literature by several authors (Singer,1922; Willius and Dry,1948; Taylor,1963; Fishman and Richards,1964; Graubard,1964; and Debus,1978).

The first recorded observations of the internal human anatomy can be traced back to the ancient Egyptians, some 3000 years B.C.. The mummification and preservation of bodies provided these people with an opportunity to observe the form and structure of the internal organs. The heart was believed to be the central distribution point for the

"vessels" that radiate to the rest of the body. Blood was thought to be synonymous with life - without blood, there is no life. There is no indication that the Egyptians had any further ideas about the functions of the blood or of the blood circulation.

The early Greeks contributed a great deal towards the early knowledge of the circulatory system. This knowledge and development of ideas was primarily due to a cultural appreciation for the explanation of natural phenomenon.

Plato (427-347 B.C.) was the first to theorize that the blood is in constant motion throughout the body. This movement was said to take place within the veins.

Hippocrates (460-370 B.C.), a contemporary of Plato, was aware of the structural differences between the arteries and the veins. He postulated that the air which is inhaled, travels from the lungs to the heart. From the heart, the air was thought to have been distributed throughout the body through the arteries. In this sense, the arteries were thought to act as "air tubes". The veins were therefore the only vessels which carried blood.

Aristotle (384-322 B.C.) was the first to hypothesize that the blood which travels in the veins is the distributor of the "transformed food" through the body. He also theorized that the heart causes the motion of the blood in the veins. Furthermore, this organ was thought to have

been the seat of intelligence and the source of bodily heat.

The idea that air is transported throughout the body in the artery "air tubes" remained unchallenged until the time of Erasistratus (310-250 B.C.). This physician proposed that the arteries do not contain air, but instead they contain blood. This arterial blood was thought to be produced in the liver.

Perhaps the most influencial figure in the history of cardiology has been Claudius Galen (138-201 A.D.). As with many of the scientists of his time, Galen's work was guided by a theme of Divine Providence. Consequently, his theories and ideas were accepted by many theologians, and thus persisted for almost fourteen centuries. Although Galen had no idea of the concept of circulation, that is, that the heart pumped blood through a network and back to itself, he did perceive the blood as being in a continuous "ebb and flow movement" through the veins or the arteries.

Galen devised a physiological scheme for the body which interrelated the processes of digestion, respiration, and the actions of the heart. According to this scheme, the heart drew in air from the lungs. The air was thought to serve three functions: 1) It served to cool the "eternal furnace" (the heart), 2) it transformed the blood in the heart to form the "vital spirit" for the body, and 3) it drew out from the venous blood the impurities of the body. The following quote summarizes Galen's "purpose" for respiration.

> Respiration in animals, as we have seen, exists for the sake of the heart, which requires the substance of the air, and scorched by the heat, desires most strongly the coolness thus provided. Penetrating with its cooling virtue, the air refreshes the heart; it then leaves it, dragging along with it the effervescent particles of a nature burnt and sooty. (from Galen's "On the Functions of the Parts of the Human Body-in Graubard, 1964, p.25)

Galen's concept of the "vital spirit" is the first account of the mixing of air with the blood. Galen does not actually use the term "mix", but he states that the air "transforms" the blood into vital spirit. This was evidenced by the difference in color between the blood of the arteries and the blood of the veins. According to Galen, the air or "pneuma" could also enter the arteries to a small degree through the surface of the skin.

As a result of the relationship between the lungs and the heart, Galen theorizes that inspiration and expiration coincide with the movement of vital spirit through the arteries.

> When the thorax, on the other hand, dilates, the lung follows suit with the chest as a whole, as in inspiration. But neither in inspiration nor in expiration do the veins undergo the same amount of dilation as the arteries because they are not assigned the same function. The latter, hollowed out by nature to receive the pneuma, must readily be filled up during the inspiration and in turn quickly emptied during expiration and the production of voice. Since the veins serve as reservoirs of nourishment, they need not dilate with inspiration or contract with expiration.... (from Galen's "On the Functions of the Parts of the Human Body-from Graubard,1964, pp.26 & 28)

Food was thought to be mixed with the blood in the liver and thus distributed to the body through the veins. Consequently, the venous and arterial systems were seen as having unique "functions" and therefore were quite unrelated.

Galen's physiological scheme received universal acceptance throughout the middle ages up until the pre-renaissance period. Ibn Nafis (1210-1270), an Arab physician born in Damascus, was the first to put forth a major criticism of the Galenian doctrine. He proposed that the blood was "aerated" not in the heart, but instead within the lungs. Ibn Nafis still accepted much of Galen's theory by acknowledging the two "types" of blood from the veins and the arteries.

The first physiologist to correctly describe the circulation of blood as we see it today was William Harvey (1578-1657). Until this time, the blood was thought to have flowed back and forth in two directions in both the veins and the arteries. Harvey postulated that the aerated blood flowed from the lungs through the heart and the arteries to the rest of the body. Although he could not see them, he theorized that the blood flowed through small "communicating vessels" from the arteries to the veins. This blood then returned to the heart. In this sense, Harvey had schematized the circulatory system as being cyclical, with blood flowing unidirectionally throughout the arteries and veins.

Our current conception of the heart and the

circulatory system has certainly expanded from the original ideas expressed by William Harvey, but this man stands alone as having provided the single greatest contribution to the history of this concept. From his time henceforth, the evolution of this concept has resulted from numerous contributions made from many smaller discoveries. Most of these discoveries have been directed towards the areas of microbiology, biochemistry, histology and microanatomy. These findings will not be reviewed here, as most of these do not shed light on the current problem area.

It is hoped that this historical outline of the concept of the heart and the circulatory system can serve as a reference to which the childrens' beliefs, as uncovered in the present study, may be compared. Consequently, it is assumed that the development of the ancient theories were guided by many of the same factors and limitations as are utilized in the development of the modern child's conception of this topic.

2.30 Current Health Education in Canada

Cardiovascular disease in North America has reached near epidemic proportions. Turner & Ball (1976) indicate that one male in three will have some form of arterial disease before the age of 65. This problem has created the need for an effective preventative education program in our schools.

A recent study by Byrne and Rothman (1979)

indicates that the current health education in Canada is "sadly deficient". This deficiency is said to result in three areas: curriculum aims and theory, curriculum content, and trained teaching staff.

> ....the 1978 Canadian Education Association study of health curricula in Canadian schools showed that wide discrepancies exist between school boards, schools and teachers, in the same province, concerning the subject matters of health education. Typically, what is taught is a function of teacher interest guided in large part by the availability of self-learning kits. Thus the overall picture of health education appears to be without a consistant and stable focus. (Byrne & Rothman,1979, p.10)

Byrne & Rothman (1979) further report that most provincial health curriculum guides are designed only according to the age and grade levels of the child. As a result, they appear to lack a psychological approach to instruction.

Health education in British Columbia is directed by an outdated curriculum guide, "Human Life Science"(1963). Science education does offer some health instruction to the elementary school student in areas of basic human anatomy and physiology (Stem Science and Exploring Science). However, these topics are covered only at the grade four and seven levels.

Byrne & Rothman(1978) recommend that Canadians initiate a core health cuuriculum which provides consistant up-to-date information, and both attitude and skill development. Further, they suggest that this curriculum be

designed according to modern psychological theory.

The present study attempts to provide the basis for educators to develop such a psychologically based curriculum for health instruction in Canada. It is felt that by identifying some of the typical children's belief structures about the heart and the circulatory system, these may be used by curriculum developers to produce materials which emphasize a particular strategy for certain "misconceptions". Also, the knowledge of these beliefs may help to decide the appropriate age for the introduction of certain health curricula into our schools.

2.40 Pedagogical Context of the Study

Ausubel's theory of learning provides great insight into the way that prior beliefs affect the acquisition of further cognitive structures. The following quote summarizes his ideas.

> If I had to reduce all of educational psychology to just one principle, I would say this: the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly. (Ausubel,1968,p.vi)

According to his theory, when novel ideas are continually introduced to an individual, these are modified and slowly integrated into an existing cognitive structure. Consequently, the pre-existing beliefs are "amazingly tenacious and resistant to extinction" and the "unlearning" of these beliefs "might well prove to be the most

determinative single factor in the acquisition and retention of subject matter knowledge". (Ausubel,1968)

A number of studies have illustrated the persistance of intuitive beliefs in science, despite instructional efforts to replace them. (Driver,1973; Rowell and Dawson,1977; Driver,1981)

Driver and Easley (1978) have suggested the importance of investigating the nature of these belief structures, and they recommend that a distinction be made between two types of investigations.

Investigations where students' beliefs are assessed in terms of their conformance to an accepted criterion are termed "nomothetic studies" (Driver & Easley,1978). These studies can be used to establish norms of conceptual development in learning science. An example of this is a study which attempts to correlate some form of data with the Piagetian developmental stages so as to determine the sequential order of curricular presentation, or the most effective age for introducing a concept into the curriculum.

Investigations where students' beliefs are assessed in their own terms without reference to an externally accepted criterion are called "ideographic studies" (Driver & Easley,1978). The value of these studies is that they can "raise the awareness of the possible perspectives pupils may bring and difficulties they may have, and hence enable more effective communication to take

place". (Driver & Easley,1978)

By understanding the nature of these intuitive beliefs, it may be possible for educators to take children on a step-by-step path from their pre-existing ideas to the acquisition of desired conceptual outcomes. This suggestion is revealed in the following statement.

> What the teacher has in mind may well be the desirable destination of a thinking process; but a learner needs to trace the steps from the familiar to the new, from the fact or idea he possesses, to that which he is to acquire. In other words, the learner has to make a journey in thought for himself. (The Bullock Report,1975, from Driver,1981,p.100)

Driver (1981) suggests that by implementing the appropriate activities in science, these may allow students to disprove their "alternate interpretations" as well as to affirm the accepted views. In an Ausubelian sense, this implies that pre-existing beliefs become "progressively differentiated" as they are "subsumed" with desired ideas. Consequently, this progressive differentiation should eventually lead to the desired outcome if the appropriate intermediary steps are taken. In order to know which "appropriate activities" to implement, the educator must first ascertain the nature of the pre-existing belief structures.

One of the early pioneers in the investigation of childrens' belief structures was Jean Piaget. This is revealed in his two books "The Childs' Conception of the

World"(1929) and "The Childs' Conception of Physical Causality"(1930). Piaget was not so much interested in the content of these beliefs, but rather in the thought processes or the methods of thinking which children use to explain their beliefs. Much of this work later formed the basis of his theory of logical structures.

In the past half decade there has been a number of studies which have explicitly investigated the nature of children's belief structures.(Aguire,1978; Kargbo, Hobbs and Erickson,1980; Erickson,1979; Deadman and Kelly,1978; Brumby,1979; Kuhn,1979; McCloskey, Caramazza, and Green,1980; Nussbaum and Novak,1976). Each of these investigations indicate two basic points: a) children do indeed possess a number of alternate ideas about concepts usually taught in the school system, and b) in most cases these ideas can be grouped into a manageable number of categories or types for the purpose of subsequent instruction.

Much of the current research on concept development in science education has focused towards the physical sciences and very little has been directed towards studying children's beliefs in the area of biology. The work of Deadman and Kelly(1978) and Brumby(1979), both centered on uncovering student beliefs about the concepts of evolution and heredity. It was a conclusion of both studies that most students intuitively hold a Lamarkian interpretation of evolution. In each investigation the pre-

existing beliefs were identified and these were used to recommend special strategies for instruction.

Another study directed towards concept development research in biology was Kargbo, Hobbs and Erickson's(1980) work on student beliefs about the concept of inheritance. In similarity to the work of Deadman and Kelly(1978), this investigation explored the nature of these beliefs by means of an open-ended interview technique. It was felt that this method allowed for the detection of very "subtle conceptual structures and emphases which written testing or other diagnostic techniques rarely do". (Deadman & Kelly,1978). Like the preceding two studies, specific teaching strategies were recommended on the basis of the beliefs uncovered.

A recent paper by Erickson (1981) has attempted to summarize the scope and direction of much of the current research which directs itself towards uncovering student beliefs about science concepts. He suggests that a four-phase approach might be used to develop teaching strategies which take into account student intuitive beliefs. "Phase One" of this scheme essentially consists of collecting a set of inventories of student intuitive beliefs. "Phase Two" involves the validification of these belief inventories in a classroom setting. Erickson proposes that "phase three" involve the formulation of instructional strategies which are based upon trends in the student belief structures. These strategies would be applicable to both the teacher and the curriculum developer. Erickson's "final phase" consists

of the implementation and evaluation of these instructional stategies.

To date there has been very little research in which instructional strategies have been designed to correspond with student intuitive beliefs ("phase three" in Erickson's scheme). Perhaps Nussbaum and Novick (1980) have proceeded the furthest in this area by designing a teaching strategy for the concept of the particle model of air.

The present study investigates childrens' beliefs about the human circulatory system. The investigator takes an ideographic approach to the analysis of the data, in the sense that the beliefs which are uncovered are not assessed with respect to the current "accepted" theory of the system.

This investigation of the childrens' beliefs about the circulatory system is significant since:

(a) a diversity of belief structures are possible for this concept area.

(b) some curricula implicitly assume that children have a basic understanding of the body with respect to its structure and function.

(c) no previous work on the development of concepts related to the human circulatory system have been sited in the literature.

Although this study is confined only to the first stage of Erickson's instructional development scheme (1981), it is hoped that the beliefs which are uncovered in this work will serve to provide teachers and curriculum developers with a more detailed perspective which will allow

them to construct instructional materials or teaching strategies to promote a more effective education for school children.

CHAPTER THREE

METHODS

3.00 Introduction

This chapter discusses three aspects of the methodology used in this study. These are:

(1) The subjects.

(2) The rationale for using the clinical interview technique.

(3) The interview procedure.

3.10 The Subjects

Thirty-two children aged from seven to fourteen years were selected according to three criteria: 1) each had to be willing to partake in the study, 2) they had to be "normal" achievers at school, and 3) they had to have written consent from their parent or guardian. (Refer to Appendix 1 for a copy of this letter of consent). Each of these criteria was confirmed by the teacher prior to these interviews.

Due to the wide diversity of health curricula in Canadian schools (Byrne and Rothman,1979), it was decided that previous instuction in this concept area should not be a selection-criterion for this study. However, at the end of every discussion, each child was asked if "they had ever talked about the body at school."

Eight students each were selected from grades 2, 4, 6, and 8. In order to check for any beliefs which might

be related to the different background experiences of boys and girls, equal numbers of both sex were included for each grade. Table 3.1 summarizes the sample of students interviewed.

Characteristics of Interview Subjects

GRADE	SUBJECTS	TOTAL	AGE RANGE	AVERAGE AGE
2	4 males:4 females	8	7:5 - 8:7	7:9
4	4 males:4 females	8	9:5 - 10:2	9:10
6	4 males:4 females	8	11:5 - 12:4	11:9
8	4 males:4 females	8	13:5 - 14:6	13:11

Students were selected from two schools in the Greater Vancouver area of British Columbia - one was an elementary school and the other was a junior secondary school. Both are located in predominantly middle-class residential areas. The investigator made no attempt to determine the parental occupation of these children, since the sample was already inappropriate for generalizing to a broader population due to its small size and lack of randomness. Therefore, the findings of this study can only be "officially" generalized to the sample used herein.

However, due to the exploratory and descriptive nature of this investigation, it is being hypothesized that the beliefs uncovered from this sample may well be representative of "typical" children of similiar age and grade. Further studies in this area are clearly required to confirm this thesis.

3.20 Rationale For Using the Clinical Interview Method

Much of Piaget's early research in child psychology was conducted using the clinical interview technique. In these clinical interviews both the interviewer and the subject became actively involved in a discussion which was relevant to the investigation. Often, the child's answers determined the course of questioning. Hence, the entire format of these interviews could be altered by allowing the child to pursue a discussion in an area of his or her own interest. It was felt that this technique provided the greatest flexibility by permitting children to expand upon many of their "natural mental inclinations" and "spontaneous interests". (Piaget,1929)

Piaget (1929) suggested that the clinical interview may reveal five types of responses from the subject; answers at random, romancing, suggested conviction, liberated conviction, and spontaneous conviction. In order to discriminate between these types of responses, Piaget suggested that further probing questions should be used to determine whether or not the statement was a genuine product of the child's cognitive structure and not something

suggested by the interviewer or an "on the spot" invention.

The present study utilized a modification of Piaget's clinical interview technique. In an attempt to control the uniformity of questions to all subjects, a set interview protocol was addressed to each child. The type of questions and their relative ordering in this protocol was largely determined by an earlier pilot study. However, in keeping with the Piagetian interviews, individualized probing questions were used in an attempt to determine a deeper understanding of the child's response. Also, for many subjects, this probing served to shed light on different facets of their belief structure which they had not previously considered.

This investigation did not employ specific tasks such as the characteristic Piagetian tasks which require the subject to make a prediction about the possible outcome of an experiment. However, certain activities were used during the course of the interview which served to facilitate the general flow of the discussion.

Each interview was tape-recorded so that the data could be later transcribed. Also, this served to add further validity to the study by allowing others to verify each child's belief as summarized by the investigator.

3.30 The Interview Procedure

The data for this study were all collected during a one-week period in the month of May, 1981. Students were interviewed during the hours of 9 a.m. and 3 p.m. in a quiet room located somewhere within each school. These discussions each lasted about 20 to 30 minutes in duration.
In an attempt to reduce student collaboration between interviews, each child was asked at the end of each discussion "not to discuss any of the things talked about in this conversation" with their classmates. Also, efforts were made to complete all the student interviews from each grade in one day.

The format of the interview for this study can be divided into two parts. The purpose of the first part was to introduce the topic of discussion, and to create a relaxed informal atmosphere for the questions and answers which were to follow in part two. It was thought that such an atmosphere would help to reduce the student inhibitions and hence promote the greatest liberation of ideas.

The initial information which was collected in part one included a record of the subject's name, grade, birthdate and sex. Following this, a few minutes were spent casually chatting with the students. In this discussion the children were told that the interviewer was interested in their ideas on how they thought the body works. It was explained that there were no right or wrong answers to any of the questions that they would be asked. In addition, the

students were asked if a tape-recording could be made of the conversation.

The protocol of questions which followed in part two of the interviews was designed to uncover the child's beliefs about the following three research areas:

1) What is the function of the heart?

2) What are the paths and methods of blood circulation?

3) What are the functions of the blood?

3a) How is the blood related to the respiratory system?

3b) How is the blood related to the digestive system?

If during the subsequent interview the child appeared to be "stumped" at any time, he/she was again reminded that there were no "right or wrong answers" to any of the questions.

As a result of the individualized probing, it may have been possible for students to answer certain questions before they were addressed in the protocol. In such cases, these questions were not repeated.

The following is the standardized protocol of questions which were used in this study.

I=interviewer

I1: Have you ever heard of the heart?

Activity 1: Here is a drawing of the human body (see

Figure One) Could you draw a picture of the heart on this drawing? Be sure to show: a) where it is found in the body, b) its size, and c) its shape.

Activity 2: This is a stethoscope. Do you know what this is used for? Place the stethoscope on the chest. Can you hear anything?

I2: What is causing that sound?

I3: What do you think the heart does?

I4: Have you ever heard of the pulse?

Activity 3: Feel the pulse on the side of the neck.

I5: What does it feel like? Can you describe it?

I6: What do you think is causing that movement in your neck?

I7: What would happen if we were to get a deep cut on the end of our finger from a sharp piece of glass?

I8: If we were cut with this glass anywhere on our bodies would we still bleed? Why?

I9: How does the blood get to these places in our bodies?

I10: Is the blood in the body moving or is it sitting still?

I11: What causes the blood to move in our body?

I12: Can you describe the path that a little bit of blood takes when it moves in the body?

Activity 4: Could you draw this path on the drawing of

the human body? (see Figure One)

I13: If we were cut with the sharp piece of glass on our wrists or on our necks, would we bleed the same amount
as if we were cut on our finger?

I14: How do we get blood?

Activity 5: Turn your hand so that your palms are down on the table. Notice the green lines on the top of your hand. Do you know what these lines are called?

I15: Why do we have these in the body?

I16: Can you tell me where these (veins) go in the body? Do they all start and end somewhere in the body?

I17: What direction or which way does the blood move in these veins?

I18: Are the blood vessels all the same size in the body?
Where are the largest and the smallest ones found?

I19: Have you ever heard of a heart attack? What happens when someone has a heart attack?

I20: What happens when your heart stops beating? (why do you die if your heart stops?)

I21: What does blood do for the body? Why do we have blood in us?

I22: What does every part of the body need in order to live?

Alternative 1: If the subject indicates "food" or the "diges- tive system" at I21 or I22, then proceed to I30 and answer questions I30 to I36. If not, proceed to Activity 5 and answer questions I23 to I36.

Activity 5: Place a bag over your mouth. Plug your nose and breathe normally. Watch the bag. Why does it move? What causes it to move?

I23: Where inside us does the air go when we breathe?

I24: Do we need air in order to live? What happens if we can't get air?

I25: Why do we take air inside us? Why do we breathe?

I26: What happens to the air once it is inside us?

I27: What parts of the body need air in order to live?

I28: How does the air get from our (body part(s) from I23) to these (body part(s) from I27)?

I29: Does the heart have anything to do with our breathing?

I30: Where does the food go after we have swallowed it?

I31: Do we get rid of all the food in us when we go to the bathroom?

I32: Do we need food in order to live? What does food do to keep us alive?

I33: What parts of the body need food (for growth and energy-I32)?

I34: How does the food get to these parts of the body so that it can be used (for growth and energy-I32)?

I35 (if necessary): What part of the body would most likely carry the food to these parts?

I36 (if necessary): You were saying earlier that we had blood inside us. Does this blood ever touch the food as it goes through us?

Alternative 2: Proceed to Activity 5 and answer questions I23 to I29 (if these haven't yet been addressed to the subject).

I37: Have you ever talked about the body at school?

This standard protocol of questions was constructed so that the subjects could continually add to the description of their belief structures as they proceeded with the interview. Therefore a complete evaluation for each of the research questions could only be carried out after reviewing the entire interview format.

CHAPTER FOUR

ANALYSIS

4.00 Introduction

Two factors will be considered in this chapter: the methods of analysis, and the results of the investigation.

The "methods of analysis" section describes the procedure which was employed to interpret and summarize the raw data collected during the student interviews.

In the second section, a "conceptual inventory" of children's beliefs has been developed for each research question considered in this study. These beliefs have been categorized to illustrate the trends or similarities which correspond to the age (grade) or the sex of children. These categories of beliefs have been presented in tables of "frequency distribution". In order to show how the investigator has classified these beliefs, excerpts from student interviews have been quoted.

4.10 Methods of Analysis

The aim of this study has been to identify children's beliefs about the following three major research questions (henceforth called "major questions"):

1. What is the function of the heart?
2. What are the paths and methods of blood circulation?

3. What are the functions of the blood?

3a. How is the blood related to the respiratory system?

3b. How is the blood related to the digestive system?

Some of these major questions have been further divided into what can be called "research subquestions" (henceforth called "subquestions"). Consequently, the content of each major question contains the sum of its constituent subquestions. Below are listed the major questions with their corresponding subquestions.

Major Question 1 - What is the function of the heart?

Major Question 2 - What are the paths and methods of blood circulation?

Subquestion 2.1 - What is the pulse?

Subquestion 2.2 - How is the blood distributed throughout the body?

Subquestion 2.3 - How do we get blood?

Subquestion 2.4 - What are the veins and where do they go in the body?

Major Question 3 - What are the functions of the blood?

Major Question 3a - How is the blood related to the respiratory system?

Subquestion 3a.1 - Where does the air go when we inhale it?

Subquestion 3a.2 - Is the air distributed to other parts of the body, and if so, how is it distributed?

Major Question 3b - How is the blood related to the digestive system?

Each child's interview data was later transcribed to produce a summary of their beliefs or ideas about each of these major questions or subquestions. Consequently, nine summaries of beliefs were produced from each interview.

(Beliefs about Major Questions 2 and 3a were not tabulated due to the reduction of these into subquestions). For an exemplary transcript of a student interview and corresponding belief summaries, refer to Appendices 2,3,4 & 5. These nine belief summaries of each child were compared to those of the other children in order to note the presence of any trends or consistencies. These trends in belief patterns were then categorized and further examined in terms of the subject response frequency. This response frequency is illustrated in tabular form. It differentiates the respondents of each belief category according to their grade, sex, and grade-sex interaction.

As a result of this analysis, a "conceptual inventory" has been generated for each of the nine research questions. This inventory illustrates the many different beliefs which children possess about each of the questions.

4.20 Results of the Investigation

4.21 The Format of the Conceptual Inventory

In order to generate a conceptual inventory for each major question or corresponding subquestion, similiar trends in belief have been categorized together. The investigator shows how each belief category was derived by quoting excerpts from the student interviews. In addition, information is presented in tabular form which indicates the grade and the sex of the children who possess these beliefs.

The conceptual inventories are presented according

to the following format:

1. The major question and subquestion (if present) and the interview questions which correspond to this.
2. A list of the total belief categories which are related to each major question or subquestion, and the number of respondents in each belief category.
3. Exemplary excerpts from the interview which correspond to each belief category.
4. General comments about the children's beliefs about each major question and subquestion (if present).
5. The "table of response frequency" for each major question or subquestion.

4.22 The Results

1) Major Question 1: What is the function of the heart? (I1 - I4)

Total Belief Categories for Major Question 1

1-A: Air travels to the heart where it is mixed with blood, this mixture is then pumped to the rest of the body. (n=5)

1-B: Air travels to the heart where it is separately pumped through the body. The heart also pumps blood through the body. (Air and blood travel through separate passages). (n=3)

1-C: Air travels to the heart where it is then pumped out of the body during exhalation. The heart also pumps the blood through the body. (Air and blood are not mixed.) (n=3)

1-D: The heart only pumps blood through the body. (n=17)

1-E: Both food and air travel independently to the heart where they are mixed with blood. This mixture is then pumped to the rest of the body. (n=2)

1-F: No idea of the functions of the heart. (n=2)

Exemplary Interview Excerpts Corresponding to Belief Categories (M.Q.1)

Belief Category 1-A: Air travels to the heart where it is mixed with blood, this mixture is then pumped to the rest of the body. (n=5)

George (11:8 - Grade 6)

S: "When you breathe it makes your heart beat by breathing air into it and making it pump. Like when you inhale, it pumps out, and when you exhale it pumps in. When you inhale air, it (the heart) goes bigger because you've got air in it."

I: "You were saying earlier in our discussion that the heart pumped blood. Now you are saying that the heart is filled with air."

S: "Well it (the air) goes into the blood."

Belief Category 1-B: Air travels to the heart where it is pumped through the body. The heart also pumps blood through the body. (Air and blood travel through separate passages). (n=3)

Neil (10:2 - Grade 4)

S: "When it pumps it vibrates the blood and it's moving around."

S: (later) "Like the heart is beating, and the air is just travelling around, and some of the air goes to your neck and face. When you breathe another time the old air goes out the nose."

I: "How does this have to do with the heart?"

S: "The heart is beating and it travels the air up here (points to head), it blows it up here."

Jack (7:5 - Grade 2)

S: "The heart it makes the blood move, and the air it goes into your heart, so it sort of helps it."

I: "What happens to the air once it goes into the heart?"

S: "Then you breathe it out again. Then you breathe it in again."

I: (later) "Do any other parts of the body need air?"

S: "I think right there (points to side of chest) and there (points to abdomen)-(later) and a little to the brain."

I: "How does the air get down to these parts?"

S: "Not all the vessels carry blood, some carry air."

I: "How does the air get to the brain?"

S: "It travels in these things (points to veins on hand)."

I: "But you said that blood travelled in these lines."

S: "Not all of them."

Belief Category 1-C: Air travels to the heart where it is pumped out of the body (during exhalation). The heart also pumps the blood through the body. (Air and blood are not mixed). (n=3)

Julie (9:8 - Grade 4)

S: "I think as well as pumping the blood, I think it might sort of push the air out of your body and then out of your mouth so you can breathe again. The heart is beating and it pumps the air like it pumps the blood."

Belief Category 1-D: - The heart only pumps blood through the body. (n=17)

Lorna (11:10 - Grade 6)

S: "The heart brings in blood and puts it out through all your cells. It gives it to the parts of the body to keep you alive."

Belief Category 1-E: Both the food and the air travel independently to the heart where they are mixed with the blood. This mixture is then pumped to the rest of the body. (n=2)

Harry (14:2 - Grade 8)

S: "Air gets pumped into the heart, then it goes into the blood, then the blood carries it through the body. The lungs might put enough into your heart-just

the amount that it needs, then the heart just pushes it into the blood and then the blood takes it to the body."

S: (later) "It's (the food) churned into acids in your stomach, then it somehow goes through some tubes or something to your heart, and then the heart takes it and disperses it into the blood and then the blood takes it and takes it through the body."

Comments About Major Question 1 : What is the function of the heart?

Nearly all the subjects (n=30) believed that the heart causes the movement of blood throught the body. The terms "pushing" or "pumping" were the most common words to describe this function of the heart.

It is interesting to note that 13 subjects believed that air, when inhaled, travels to the heart. Seven of these thirteen children thought that the heart is the mixing place for the air and the blood. This aerated blood was thought to be subsequently distributed to the rest of the body. Three of this group of 13 thought that the heart pumps the air (separately from the blood) throughout the body. The remaining three children believed that the heart causes the air to exhale as a result of its pumping action. The 13 subjects who believed that the air travels to the heart represented an equal cross-section of the sex and age of the children interviewed.

Two subjects, each from grade 8, indicated that in addition to air, food travels to the heart from the stomach area. This food was said to mix with the blood in the heart.

Only two children failed to produce their beliefs on the functions of the heart. This may have been due to the novelty of this question, or it may have been due to the interviewer's intimidation. Both children were from grade 2.

The diagrams of the position, size, and shape of the human heart (Activity 1) were generally quite accurate. All thirty-two subjects positioned the heart in the chest region of the body. The size of this organ varied between being twice its normal size, to being about half its normal size. The shape ranged from the typical "valentine" heart, to an irregular-shaped circle. There did not appear to be any trends in age or sex which corresponded to these drawings.

TABLE ONE

Major Question: What is the major function or the heart?

Belief Categories:

1-A: Air travels to the heart where it is mixed with the blood, this mixture is then pumped to the rest of the body.
1-B: Air travels to the heart where it is separately pumped through the body. The heart also pumps blood through the body. (Air and blood travel through separate passages).
1-C: Air travels to the heart where it is pumped out of the body during exhalation. The heart also pumps the blood through the body. (Air and blood are not mixed).
1-D: The heart only pumps blood through the body.
1-E: Both food and air travel independently to the heart where they are mixed with the blood. This mixture is then pumped to the rest of the body.
1-F: No idea of the functions of the heart.

	CATEGORY					
GRADE	1-A	1-B	1-C	1-D	1-E	1-F
2	2	2	-	2	-	2
4	1	1	1	5	-	-
6	1	-	2	5	-	-
8	1	-	-	5	2	-
Females	2	1	2	8	1	2
Males	3	2	1	10	1	-
2F	-	1	-	1	-	2
2M	2	1	-	1	-	-
4F	1	-	-	2	-	-
4M	-	1	1	3	-	-
6F	-	-	1	3	-	-
6M	1	-	1	2	-	-
8F	-	-	-	2	1	-
8M	1	-	-	3	1	-

2) Major Question 2: What are the paths and methods of blood circulation? (I5 - I22)

Subquestion 2.1 What is the pulse? (I5 - I6)

Total Belief Categories for Subquestion 2.1

2.1-A: The pulse is somehow linked with the heart - no further explanations. (n=5)

2.1-B: The pulse is caused by blood running through blood vessels. (n=18)

2.1-C: The pulse is caused by breathing. (n=2)

2.1-D: The pulse is caused by your brain working. (n=1)

2.1-E: No idea what the pulse is. (n=6)

Exemplary Interview Excerpts Corresponding to Belief Categories (SQ. 2.1)

Belief Category 2.1-A: The pulse is somehow linked with the heart - no further explanations. (n=5)

Anne (7:11 - Grade 2)

I: (Subject has just felt pulse in neck). "What does that feel like?"

S: "It feels like when your heart beats."

I: "What causes that movement?"

S: "Your heart."

I: "But you said that your heart was down here (points to chest) in your diagram. What is causing this movement in your neck?"

S: "I don't know."

Belief Category 2.1-B: The pulse is caused by the blood running through the blood vessels. (n=18)

Jack (7:5 - Grade 2)

I: "What do you think is causing that movement?"

S: "Your heart."

I: "But you said that your heart was down here in your chest."

S: "Well there's these things, I don't know what they're called. They go up here (points to head) and everywhere and it pumps blood into these."

Belief Category 2.1-C: The pulse is caused by breathing. (n=2)

Kelly (7:6 - Grade 2)

I: "What does that feel like when you feel your pulse?"

S: "Going out and in."

I: "What do you think is causing that to go out and in?"

S: "Is it when you breathe?"

Belief Category 2.1-D: The pulse is caused by your brain working. (n=1)

Julie (9:8 - Grade 4)

I: (Subject is feeling pulse in neck) "Can you feel anything?"

S: "A bit - it sort of vibrates a bit."

I: "What do you think is causing that vibration."

S: "Your brain working."

Comments About Subquestion 2.1: What is the Pulse?

Although thirty subjects believed that the heart causes the movement of the blood through the body (as seen for Major Question One), only eighteen subjects thought that the pulse is caused by the heart pumping blood through the blood vessels. Thirteen of this group of eighteen were from grades 6 and 8 while only five children were from grades 2 and 4.

Five subjects could identify the relationship between the feeling of the pulse and the beat of the heart, but these children were unable to extend this concept to the movement of blood through the blood vessels. Four of these subjects were from grades 2 and 4.

Two subjects felt that the pulse is due to the flow of air while breathing. Perhaps this may have been due to the fact that the pulse was taken by feeling the carotid artery in the neck. As a recommendation for future research, the investigator suggests that the pulse should also be taken in the wrist. This part of the anatomy would be far removed from the head region, thus breathing or "brain activity" (Belief Category 2.1-D) would not offer as much bias to the child's answer.

Six children did not offer any suggestions as to the cause of the pulse. Three of these subjects were from grade 2, one from grade 4, and two from grade 6.

TABLE TWO

Major Question 2: What are the paths and methods of blood circulation?

Subquestion 2.1: What is the pulse?

Belief Categories:

2.1-A: The pulse is somehow linked with the heart - no further explanations.
2.1-B: The pulse is caused by blood running through blood vessels.
2.1-C: The pulse is caused by breathing.
2.1-D: The pulse is caused by your brain working.
2.1-E: No idea what the pulse is.

	CATEGORY				
GRADE	2.1-A	2.1-B	2.1-C	2.1-D	2.1-E
2	1	3	1	-	3
4	3	2	1	1	1
6	1	5	-	-	2
8	-	8	-	-	-
Females	3	7	2	1	2
Males	2	11	-	-	4
2F	1	1	-	-	1
2M	-	2	-	-	2
4F	2	-	2	1	-
4M	1	2	-	-	1
6F	1	2	-	-	1
6M	-	3	-	-	1
8F	-	2	-	-	-
8M	-	4	-	-	-

3) Major Question 2: What are the paths and methods of blood distribution? (I5 - I22)

Subquestion 2.2: How is the blood distributed throughout the body? (I7 - I13)

Total Belief Categories for Subquestion 2.2

2.2-A: From the heart the blood flows through veins. This flow is in one direction only. The movement of blood is from the heart to one part of the body, then to other parts, then finally back to the heart. (n=5)

2.2-B: From the heart the blood flows through the blood vessels. This flow is in one direction only. The movement of blood is from the heart to one part of the body and directly back to the heart. (n=12)

2.2-C: From the heart the blood travels through blood vessels. This flow is in one direction only. The blood is carried by the blood vessels only to the body part. No explanation is given as to how it returns to the heart. (n=9)

2.2-D: From the heart the blood flows through veins. This flow is in a back-and-forth motion in the veins. The movement of blood is from the heart to one part of the body and directly back to the heart through the same vein. (n=3)

2.2-E: The heart pumps the blood "to the body". No mention is given of this movement through blood vessels. This flow is directed only towards the body parts. No explanation is given as to how the blood returns to the heart. (n=1)

2.2-F: The heart is not associated with blood movement. This movement is caused by the movement of the body. The blood starts from the head and moves around the body in a haphazard way. (n=2)

Exemplary Interview Excerpts Corresponding to Belief Categories (SQ. 2.2)

Belief Category 2.2-A: From the heart the blood flows through the veins. This flow is in one direction only. The movement of blood is from the heart to one part of the body, then to other parts, then finally back to the heart. (n=5)

David (13:6 - Grade 8)

S: "The heart pumps the blood through the veins, I guess."

S: (later) "The heart pumps it (the blood) and it circulates."

S: (later, subject explains blood diagram - refer to Figure One) "I guess it would come down from the heart and it would come down somewhere in the leg, hang a U-turn, go back up and then go all around and then back to the heart. -And probably down his arms or something and then back to the heart."

Belief Category 2.2-B: From the heart the blood flows through blood vessels. This flow is in one direction only. The movement of blood is from the heart to one part of the body and directly back to the heart. (n=12)

Allen (9:9 - Grade 4)

I: "How does the blood get to these parts in the body?"

S: "The heart pumps it through these veins."

S: (later, subject speaks about his diagram - refer to Figure Two) "One line goes down and the other goes up to put the bad blood back in the heart."

I: "What do you mean by "bad blood"?"

S: "It's the blood that takes all the dirty stuff out of your hands and things."

I: "What does the new blood have that the bad blood doesn't have?"

S: "The bad blood is a bit dull, and the new blood is all red. I just heard on television that the bad blood just isn't very good."

S: (later) "When the bad blood goes into the heart it performs new blood and then the new blood comes out and the bad blood comes back into the heart. It keeps going around."

Belief Category 2.2-C: From the heart the blood travels through blood vessels. This flow is in one direction only. The blood is only carried by these blood vessels to the body part. No explanation is

given as to how it returns to the heart. (n=9)

Neil (10:2 - Grade 4)

S: (refer to Figure 3). "When the heart is beating, it moves the blood and the blood gets into the vein, and the vein it travels down the arm to your hands."

I: "If you've got blood flowing into your hands, won't they just get filled up with blood?"

S: "When it's filled up, it will stop there until the blood rests."

I: "Can you tell me a little more?"

S: "If the hand has too much blood in it, it won't go there anymore, it will travel somewhere else."

Belief Category 2.2-D: From the heart, the blood flows through the veins. This flow is in a back-and-forth motion in the veins. The movement of blood is from the heart to one part of the body and directly back to the heart through the same vein. (n=3)

Lorna (11:10 - Grade 6)

S: "The heart pumps it and distributes the blood to the veins."

S: (later) "The veins bring the blood to the places it has to go."

I: (later - refer to Figure 4) "If the blood moves in one direction, doesn't it build up pressure at the end of your foot and hand?"

S: "No, because in the same blood vessel they go both ways. Like, one part goes this way (points up towards heart), and one part goes this way (points towards foot)."

I: "I don't understand what you mean."

S: "In the vein it goes both ways."

Belief Category 2.2-E: The heart pumps the blood "to the body". No mention is given of this movement through blood vessels. This flow is directed only towards the

body parts. No explanation is given as to how the blood returns to the heart. (n=1)

Louise (8:0 - Grade 2)

I: "How does the blood get to all the spots in the body?"

S: "Air, when you breathe it in, it goes and pushes the blood."

I: "Where does the blood go when it travels around the body?"

S: "It stays at the outside."

I: "Outside of what?"

S: "Underneath your skin."

I: "Do you know what causes the blood to move?"

S: "The heart and the air. When you breathe in it goes into your heart, then it all pumps it (the blood)."

-This subject later thought that the veins acted as "connectors" of the different parts of the body.

Belief Category 2.2-F: The heart is not associated with blood movement. This movement is caused by the movement of the body. The blood starts from the head and moves around the body in a haphazard way. (n=2)

Margaret (7:10 - Grade 2)

I: "Does the blood move in the body?"

S: "Sometimes it sits still, sometimes it moves."

I: "What causes it to move?"

S: "Like when I move, it starts to move."

I: "How does the blood get around the body?"

S: "By bones pushing."

(Refer to Figure 5 for this subject's ideas on the directions that the blood takes when it moves around the body.)

Comments about Subquestion 2.2: How is the blood distributed through the body?

There appears to be five categories of belief as to how the blood moves in the body.

In the first category (Belief 2.2-A), the blood is thought to move through the blood vessels so as to complete a "circle" to and from the heart. However this path of movement extends in a continuous manner throughout the entire body before it returns to the heart. For example, the blood would flow from an arm to a leg, then to the other leg, then to the other arm, and finally back to the heart. All five subscribers to this belief were from grades 6 and 8 (one in grade 6 and four in grade 8).

In the second category (Belief 2.2-B), the blood is also thought to flow unidirectionally through the blood vessels so as to complete a circulation of the blood to and from the heart. In contrast to the first category, this flow is from the heart to a body part, and directly back to the heart. This formed the largest group with n=12 (four children each from grades 4, 6, and 8).

The third category of belief (Belief 2.2-C), differed from the first two categories in that there was no indication of the circulation of blood back to the heart. These subjects believed that the blood only flows from the heart to the body part. This belief was maintained by each subject despite the following counter-suggestion made by the investigator: "won't the hand (or body part) just get filled

up with blood?". Nine children from the sample held this belief (four each from grades 2 & 4,,and one from grade 6).

The fourth belief category (Belief 2.2-D), held that the blood flows in a back-and-forth motion within each blood vessel. In this sense, the blood is circulating from the heart to the body part,and back to the heart. Three respondents subscribed to this belief.

Three children believed that the movement of blood throughout the body takes place in a haphazard manner. The blood was thought to move by some other means than through the blood vessels. All three subjects were from grade 2.

To summarize, twenty children held to a belief of the circulation of the blood throughout the body. This movement both starts and ends at the heart.

It should be noted that the term "vein" was used synonymously with "arteries". No children distinguished between the venous and the arterial system, or between veins and arteries. In this sense, the blood flow to and from the heart is through the "veins".

FIGURE 10:

Exemplary Diagram of the Human Blood

Circulation Corresponding to Belief Category 2.2 A

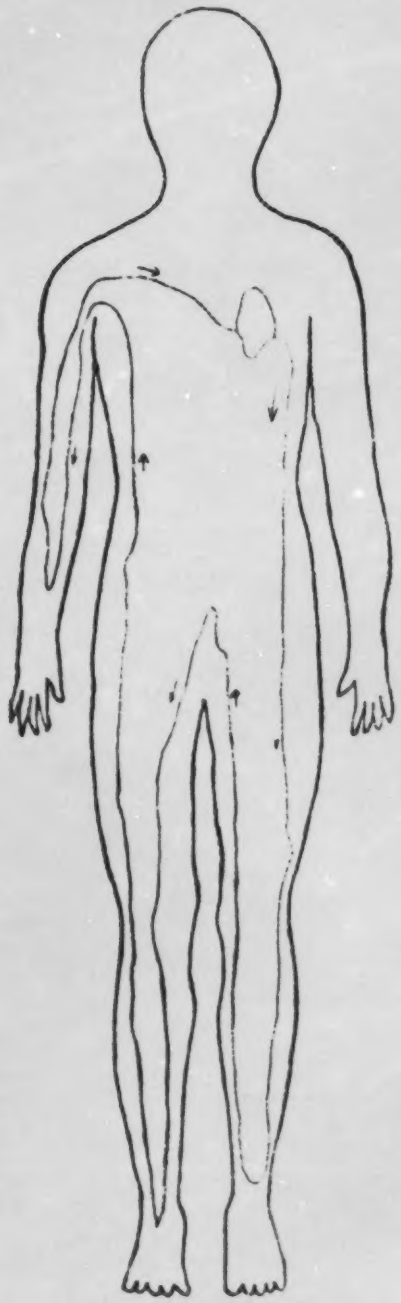

FIGURE TWO

Exemplary Diagram of the Human Blood Circulation Corresponding to Belief Category 2.2-B

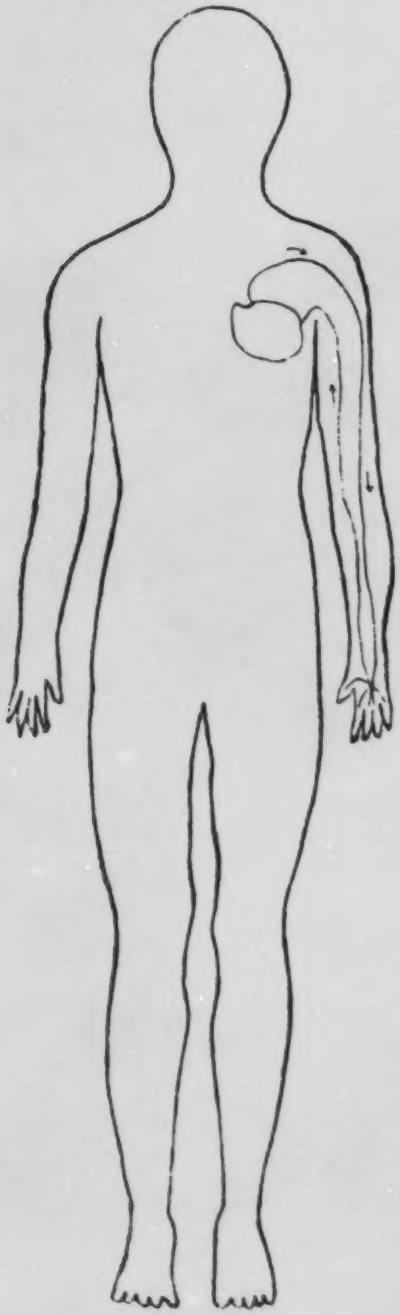

FIGURE THREE

Exemplary Diagram of the Human Blood Circulation Corresponding to Belief Category 2.2-C

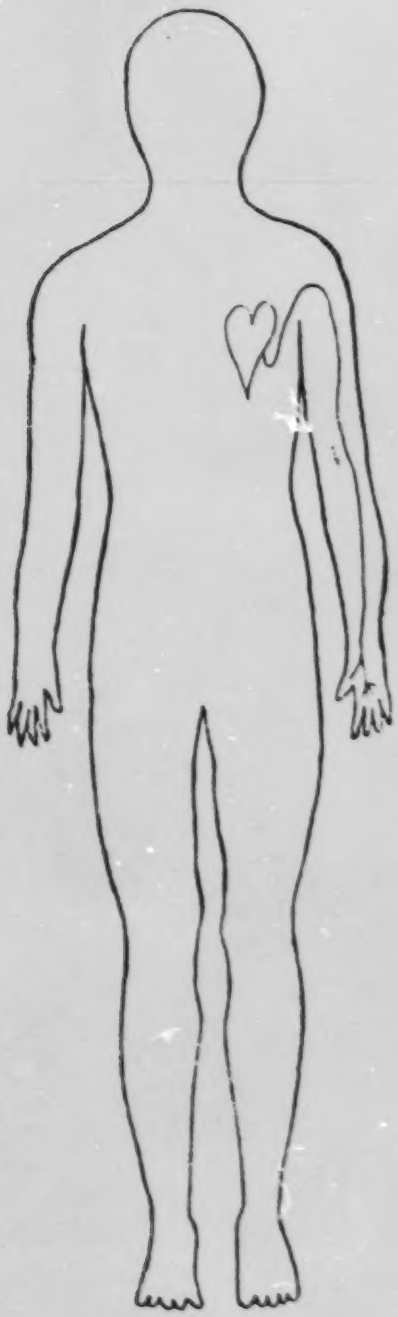

FIGURE FOUR

Exemplary Diagram of the Human Blood Circulation Corresponding to Belief Category 2.2-D

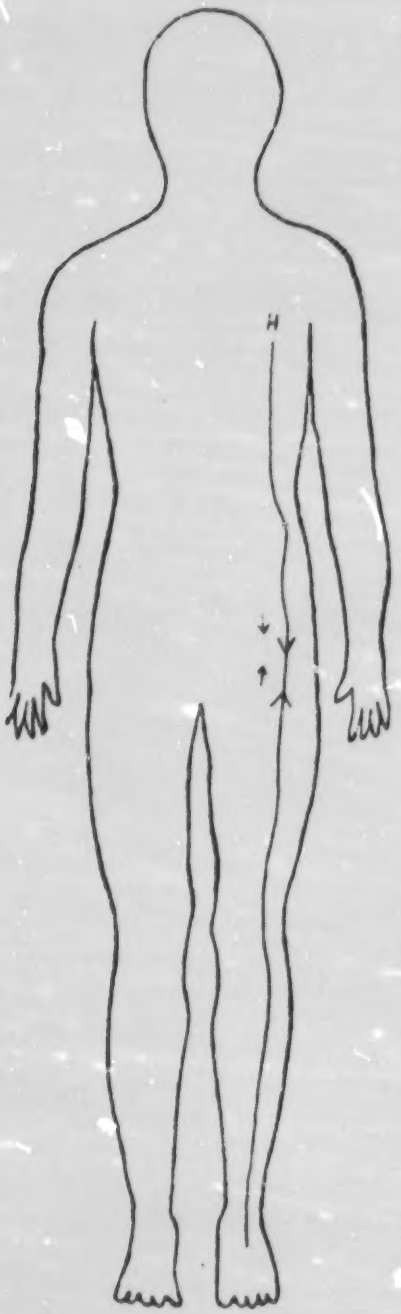

FIGURE FIVE

Exemplary Diagram of the Human Blood Circulation Corresponding to Belief Category 2.2-E

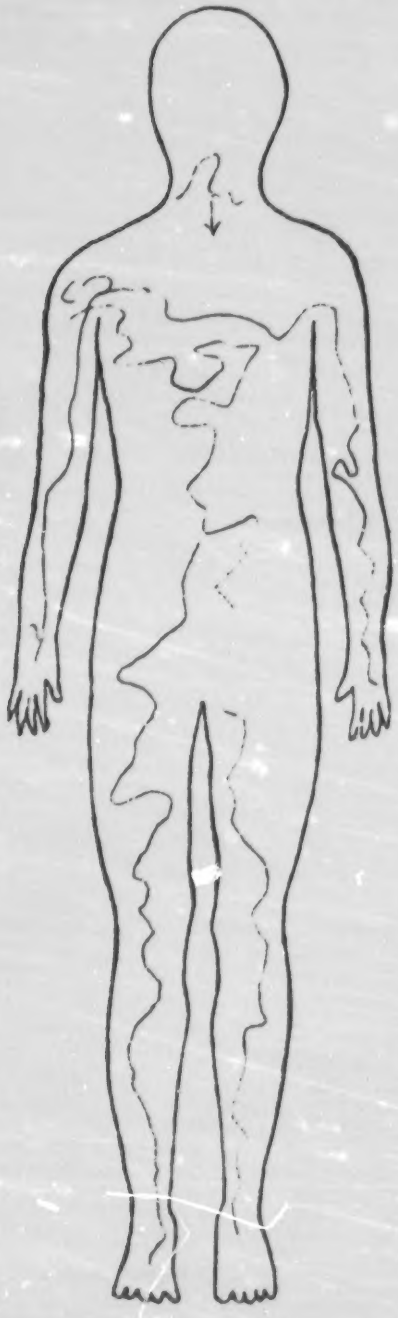

TABLE THREE

Major Question 2: What are the paths and methods of blood circulation?

Subquestion 2.2: How is the blood distributed throughout the body?

Belief Categories:

2.2-A: From the heart the blood flows through veins. This flow is in one direction only. The movement of blood is from the heart to one part of the body, then to another part of the body, then finally back to the heart.

2.2-B: From the heart the blood flows through blood vessels. This flow is in one direction only. The movement of blood is from the heart to one part of the body and directly back to the heart.

2.2-C: From the heart the blood travels through blood vessels. This flow is in one direction only. The blood is carried only to the body part by the blood vessel. No explanations are given as to how it returns to the heart.

2.2-D: From the heart, the blood flows through veins. This flow is in a back-and-forth motion in the veins. The movement of blood is from the heart to one part of the body and directly back to the heart through the same vein.

2.2-E: The heart pumps blood "to the body". No mention is given of this movement through blood vessels. This flow is directed only towards the body parts. No explanations are given as to how the blood returns to the heart.

2.2-F: The cause of blood movement is thought to be the movement of the body. The blood starts from the head and moves around the body in a haphazard way.

	CATEGORY					
GRADE	2.2-A	2.2-B	2.2-C	2.2-D	2.2-E	2.2-F
2	-	-	4	1	1	2
4	-	4	4	-	-	-
6	1	4	1	2	-	-
8	4	4	-	-	-	-
Females	2	6	3	2	1	2
Males	3	6	6	1	-	-
2F	-	-	1	-	1	2
2M	-	-	3	1	-	-
4F	-	2	2	-	-	-
4M	-	2	2	-	-	-
6F	-	2	-	2	-	-
6M	1	2	1	-	-	-
8F	2	2	-	-	-	-
8M	2	2	-	-	-	-

4) Major Question 2: What are the paths and methods of blood distribution? (I5 - I22)

Subquestion 2.3: How do we get blood? (I14)

Total Belief Categories for Subquestion 2.3

2.3-A: Blood is made in the heart. (n=21)

2.3-B: Blood is made in the stomach from the food we eat. (n=2)

2.3-C: Blood is made in the bone marrow. (n=1)

2.3-D: Blood is made from food and water - no idea where this takes place. (n=2)

2.3-E: We get blood from our head. (n=1)

2.3-F: Our blood comes only from our mothers when we are little. (n=1)

2.3-G: No idea how we get blood. (n=4)

Exemplary Interview Excerpts Corresponding to Belief Categories (SQ. 2.3)

Belief Category 2.3-A: Blood is made in the heart. (n=21)

Allen (9:9 - Grade 4)

I: "How do we get blood in our bodies?"

S: "In our heart."

I: "Can you tell me a bit more about that?"

S: "I think that when the old blood goes into the heart it performs new blood and then the new blood comes out and the old blood comes back into the heart. It keeps going around."

I: "Where do we get the blood originally?"

S: "From the heart mostly."

I: "Do you mean it's made in the heart?"

S: "Yes."

Belief Category 2.3-B: Blood is made in the stomach from the food we eat. (n=2)

Randy (9:10 - Grade 4)

I: "How do we get blood in our body?"

S: "From the good food that we eat."

I: "So you are saying that we eat the blood."

S: "When you eat it, it forms blood cells in your body."

I: "Where abouts are these blood cells formed?"

S: "In your stomach probably, or your intestines."

Belief Category 2.3-C: Blood is made in the bone marrow. (n=1)

Susan (13:11 - Grade 8)

I: "How do we get blood in the body?"

S: "Like through the bones and the marrow."

I: "Is this where the blood is made in the body."

S: "I think it's in the inside of your bones and then it goes to your heart and this distributes it to your body."

Belief Category 2.3-D: Blood is made from the food and water, no idea where this takes place. (n=2)

Jack (7:5 - Grade 2)

I: "Jack, how do we get blood?"

S: "From the food we eat."

I: "Where does the food become blood in the body - where does it change from being food to being blood?"

S: "Well, it doesn't exactly do that. Like, the proteins and stuff, it goes into some sort of thing and everything else that you eat goes in and it makes blood."

I: "Do you know where that blood is made?"

S: "I don't know."

Belief Category 2.3-E: We get blood from our head. (n=1)

Anne (7:11 - Grade 2)

I: "How do we get blood in the body?"

S: "From our head."

(This subject did not offer any further beliefs about the origin of the blood.)

Belief Category 2.3-F: Our blood only comes from our mothers when we are little. (n=1)

Greg (7:5 - Grade 2)

I: "Where do we get our blood, Kevin?"

S: "I don't know."

I: "Do you know where it's made in the body?"

S: "From the mother's heart."

I: "Well, you are a big boy now, do you think that you still get it from your mother?"

S: "But when you were little and still in the heart - yes."

I: "So you don't make blood anymore now, eh?"

S: "No."

Comments about Subquestion 2.3: How do we get blood?

Most subjects believed that the blood is made in the heart (n=21). Many of these felt that since this is "the place where the blood starts from", then "this is the place where it is made". Others thought that the blood is made in the heart from the food that we ingest. Only two subjects could suggest how this food travels to the heart for blood production (Belief Category 1-E, - Major Question 1). The twenty-one children who maintained this belief were evenly

distributed across all grades and each sex.

The relationship between blood production and the ingestion of food is seen in Belief Categories 2.3-B and 2.3-D (total N=4).

Other origins of blood production included the head (n=1-grade 2), the bone marrow (n=1-grade 8), and the maternal source of blood before birth (n=1-grade 2).

Only four children could not comment on the origin of the blood.

TABLE FOUR

Major Question 2: What are the paths and methods of blood distribution?

Subquestion 2.3: How do we get blood?

Belief Categories:

2.3-A: Blood is made in the heart.
2.3-B: Blood is made in the stomach from the food we eat.
2.3-C: Blood is made in the bone marrow.
2.3-D: Blood is made from the food and water - no idea where this takes place.
2.3-E: We get blood from our head.
2.3-F: Our blood comes only from our mothers when we are little.
2.3-G: No idea how we get blood.

	CATEGORY						
GRADE	2.3-A	2.3-B	2.3-C	2.3-D	2.3-E	2.3-F	2.3-G
2	3	-	-	1	1	1	2
4	7	1	-	-	-	-	-
6	5	1	-	1	-	-	1
8	6	-	1	-	-	-	1
Females	11	-	1	-	1	-	3
Males	10	2	-	2	-	1	1
2F	1	-	-	-	1	-	2
2M	2	-	-	1	-	1	-
4F	4	-	-	-	-	-	-
4M	3	1	-	-	-	-	-
6F	4	-	-	-	-	-	-
6M	1	1	-	1	-	-	1
8F	2	-	1	-	-	-	1
8M	4	-	-	-	-	-	-

5) Major Question 2: What are the paths and methods of blood distribution? (I5 - I22)

Subquestion 2.4: What are the veins and where do they go in the body? (I15 - I20)

Total Belief Categories for Subquestion 2.4

2.4-A: Blood flows through the veins. These extend from the heart to the body parts. (n=27)

2.4-B: Veins connect and support different parts of the body. They are not linked at all with blood. (n=3)

2.4-C: Veins help us to move our body. They extend from the head to the different body parts. (n=1)

2.4-D: Veins allow blood to flow through them. They extend from the head to the different body parts. (n=1)

Exemplary Interview Excerpts Corresponding to Belief Categories (SQ. 2.4)

Belief Category 2.4-A: Blood flows through the veins. These extend from the heart to the body parts. (n=27)

Doug (11:5 - Grade 6)

I: (Investigator refers to the veins on the top of the hand) "Why do we have these veins in the body?"

S: "To make blood go to different parts of the body."

I: "Do the veins all start and end somewhere in the body?"

S: "They start at the heart and they go all around, and they usually go back to the heart, and it pumps more blood and it goes all around your body - like a circle."

Belief Category 2.4-B: Veins connect and support the different parts of the body. They are not linked at all with blood. They are all over the body. (n=3)

Dawn (12:3 - Grade 6)

I: "Why do we have these (veins) in the body?"

S: "If we didn't have them, our fingers wouldn't stand up straight. They would just limp around. They attach to your fingers. If you didn't have them, your fingers would just limp around."

I: "Do they serve any other function?"

S: "They go up your arms. They're attached everywhere in your body."

I: "What do they do for the body? Why do we have them in us?"

S: "I think it's just to keep you straightened, or just the way you are - straight."

I: (later) "How does the blood move inside you."

S: "It runs back and forth or sideways - just like in a swimming pool when the water goes swiftly around."

Louise (8:0 - Grade 2)

I: "Why do we have these veins in the body?"

S: "To hold our knuckles on to our hand."

I: "Do we have these veins on our legs?"

S: "Yes, to keep the thigh connected to the kneecap, and the kneecap connected to the lower thigh."

Belief Category 2.4-C: Veins help us to move our body. They extend from the head to the different body parts.

Barb (9:11 - Grade 4)

I: (Investigator refers to the veins on the top of the hand). "What do these green lines do in the body, Barb?"

S: "They help you to move your hand - moving."

I: "What do they help our body do?"

S: "They help us move our hands, and our head, and our legs."

I: "Do they all start and end somewhere in the body?"

S: "They start from the hand and they end in the head."

Belief Category 2.4-D: Veins allow blood to flow through them. They extend from the head to the different body parts. (n=1)

Anne (7:11 - Grade 2)

I: (Subject previously called the green lines on the top of the hand "veins"). "Why do we have these veins in our body?"

S: "So that you can get blood into your hands and fingers."

I: "Can you tell me where these green lines go in the body? Do they all start and end somewhere in the body?"

S: "Start from your head."

I: "And where do they end?"

S: "End in your toes and hands."

Comments about Subquestion 2.4: What are the veins and where do they go in the body?

By in large, most subjects thought that the function of the veins is to allow blood movement. Twenty-seven children (equally representing all grades) believed that these structures extend between the heart and the body parts. Several of these indicated that instead of two separate veins (for input and output), one long vein might exist between the heart and the body part. For example this vein would loop around at the end of the hand and take the blood back to the heart.

Only one child suggested that the origin of the veins is in the head region.

The remaining subjects held to the belief that the primary function of the veins is to connect the body parts

so as to offer support or mobility to them. The four children in this category were in grades 2 & 6 (two in grade 2, two in grade 6).

Again there was no distinction made at any time between the venous and the arterial systems or between veins and arteries. Blood was thought to flow both to and from the heart through the veins.

TABLE FIVE

Major Question 2: What are the paths and methods of blood circulation

Subquestion 2.4: What are the veins and where do they go in the body?

Belief Categories:

2.4-A: Blood flows through the veins. These extend from the heart to the body parts.
2.4-B: Veins connect and support the different parts of the body. They are not linked at all with blood.
2.4-C: Veins help us to move our body. They extend from the head to the different body parts.
2.4-D: Veins allow the blood to flow through them. They extend from the head to the different body parts.

	CATEGORY			
GRADE	2.4-A	2.4-B	2.4-C	2.4-D
2	5	2	-	1
4	7	-	1	-
6	7	1	-	-
8	8	-	-	-
Females	11	3	1	1
Males	16	-	-	-
2F	1	2	-	1
2M	4	-	-	-
4F	3	-	1	-
4M	4	-	-	-
6F	3	1	-	-
6M	4	-	-	-
8F	4	-	-	-
8M	4	-	-	-

Comments About Major Question 2: What are the paths and methods of blood distribution?

Most subjects believed that the blood moves through the body in blood vessels (n=29, Subquestion 2.2). Further, all of these children thought that the source of this blood flow is the pumping heart.

As an application to these main conceptual beliefs, eighteen subjects, mainly from grades 6 and 8, were able to correlate the movement of the pulse to the movement of the blood through the blood vessels.

Twenty subjects, equally representing grades 2 to 8, viewed the movement of blood as completing a cycle within the body. This circulation of blood was said to have started and ended at the heart. Seventeen of these twenty subjects believed that this blood flow in the body occurs as a result of blood flowing unidirectionally within the blood vessels. Thus, only three children thought that the blood flows to and from the heart in the same vessel.

Two-thirds of the subjects held to the belief that the heart is the site of blood production in the body. Some subjects suggested this as a result of the "key role" which the heart plays in the movement of the blood.

6) Major Question 3: What are the functions of the blood? (I21 & I22)

Total Belief Categories for Major Question 3

3-A: Blood is essential for life. No further explanations are given. (n=9)

3-B: Blood carries food and air throughout the body. (n=8)

3-C: Blood carries food throughout the body. (n=5)

3-D: Blood carries air throughout the body. (n=2)

3-E: Blood heats the body and it also carries food. (n=2)

3-F: Blood carries food and air throughout the body, it also fights bacteria in the body. (n=1)

3-G: No idea of the function of the blood. (n=5)

Exemplary Interview Excerpts Corresponding to Belief Categories (M.Q. 3)

Belief Category 3-A: Blood is essential for life. No further explanations are given. (n=9)

Doug (11:5-Grade 6)

I: "Why is blood so important to the body?"

S: "Because, like if you didn't have any blood you wouldn't be alive. Because, like the bones in you fill the shape of you and then like blood flows through so that you can do movements and it makes your heart beat and if your heart didn't beat you'd be dead."

I: "But why do we all have blood in us? What is so important about the blood?"

I: "It keeps you going."

I: "Do you know how it keeps us going?".

S: "Blood makes your heart pump."

Belief Category 3-B: Blood carries food and air throughout the body. (n=8)

Calvin (11:5 - Grade 6)

I: "Why is the blood so important to the body?"

S: "Well it keeps it going. And when you eat something, the nutrients go into the blood and the blood is like food for the rest of the body and it carries oxygen."

I: "When you breathe, where does the air go?"

S: "It goes into your lungs and it goes into your blood at the lungs.

Belief Category 3-C: Blood carries food throughout the body. (n=5)

Diane (14:4 - Grade 8)

I: "Why do we have blood in us? Why is it so important?"

S: "It carries nutrition and feeds your muscles so that they become strong. If your blood just all of a sudden sits, then you're not active,you can't move around. If it sits then it will go all to your feet, right, because it will stop moving. So you won't be able to go anywhere."

I: "What does every part of the body need in order for a person to live?"

S: "Blood, nutrition, liquids, and muscles - mostly blood though."

Belief Category 3-D: Blood carries air throughout the body. (n= 2)

Brad (7:8 - Grade 2)

I: "What does blood do for the body, Brad?"

S: "I don't know actually."

I: (later in interview) "Do our arms and our legs need air?"

S: "Yes I think so."

I: "You said that when you took air in, it went from your mouth down to your heart. How does the air get to your arms and legs?"

S: "I think that it goes through your veins."

I: "But you said that blood went through the veins."

S: "Well it's the same thing, it can go through the veins because it's invisible. It goes with the blood."

Belief Category 3-E: Blood heats the body and it also carries food. (n=2)

Brenda (11:5 - Grade 6)

I: "What does the blood do for the body?"

S: "Well it helps us to move, and when you squeeze your finger for a long time the blood stops circulating and it kind of makes your finger dead."

I: "Well what is it that the blood does to make it alive?"

S: "It circulates and keeps us warm."

I: "Why is the blood so important that we can't be without it?"

S: "It keeps us alive. It takes some things that we need to the parts of the body."

I: "Do you know what these are?"

S: "No." (later in interview) "Well the things that we need , like the vitamins go to the heart and into the blood again through the veins and to the other parts of the body."

Belief Category 3-F: Blood carries food and air throughout the body. It also fights bacteria in the body. (n=1)

Harry (14:2-Grade 8)

I: "Why do we have blood in us? Can you think of any functions of the blood?"

S: "To bring things through your body like nutrition to the different parts of the body."

I: "Does it bring anything else?"

S: "Blood cells."

I: "What does every part of the body need for us to live?"

S: "I guess it needs red and white blood cells."

I: "What's in red and white blood cells that makes them so important?"

S: "Like things that fight off bacteria and disease."

(Subject later indicated that air was transported through the blood system)

Comments About Major Question 3: What are the Functions of the Blood?

Twenty-seven of the subjects interviewed, believed that the blood has at least one function. All of the children who had no ideas about its possible functions were from grade two.

The beliefs about the functions of the blood ranged from a simple conception that it is essential to life (n=9 - all grades), to more complex beliefs such as "it carries food and air" (n=8),"it heats the body" (n=2), or "it fights bacteria" (n=1).

The subjects who thought that the blood carries food and air were predominently from the older grades (6 & 8). The same was true for the belief that the blood fights bacteria (subject was from grade 8).

It is interesting to note that most students, when asked about the functions of the blood at I21 were unable to give a complete summary of this belief. Thus, most children suggested that the blood carries food and/or air at a later time in the interview when the questions were directed towards the respiratory and digestive systems.

TABLE SIX

Major Question 3: What are the functions of the blood?

Belief Categories:

3-A: Blood is essential for life - no further explanation.
3-B: Blood carries food and air throughout the body.
3-C: Blood carries food throughout the body.
3-D: Blood carries air throughout the body.
3-E: Blood heats the body and it also carries food.
3-F: Blood carries food and air throughout the body. It also fights bacteria in the body.
3-G: No idea of the functions of the blood.

	CATEGORY						
GRADE	3-A	3-B	3-C	3-D	3-E	3-F	3-G
2	1	1	-	1	-	-	5
4	4	-	2	1	1	-	-
6	3	3	1	-	-	-	1
8	1	4	2	-	-	-	1
Females	5	4	1	1	2	-	3
Males	4	4	4	1	-	1	2
2F	1	-	-	-	-	-	3
2M	-	1	-	1	-	-	2
4F	2	-	-	1	1	-	-
4M	2	-	2	-	-	-	-
6F	2	1	-	-	1	-	-
6M	1	2	1	-	-	-	-
8F	-	3	1	-	-	-	-
8M	1	1	1	-	-	1	-

7) Major Question 3a: How is the blood related to the resiratory system? (I23-I29)

Subquestion 3a.1: Where does the air go when we inhale it? (I23-I29)

Total Belief Categories for Subquestion 3a.1

3a.1-A: The air goes to the lungs in the chest. (n=18)

3a.1-B: The air goes to the lungs and the heart. (n=6)

3a.1-C: The air goes to the heart. (n=7)

3a.1-D: The air goes to the stomach (with the food) and also to the legs. (n=1)

Exemplary Interview Excerpts Corresponding to Belief Categories (SQ. 3a.1)

Belief Category 3a.1-A: The air goes to the lungs in the chest. (n=18)

Kay (13:5 - Grade 8)

I: "Where does the air go when you breathe it into your body?"

S: "Into your blood"

I: "How does it get into your blood?"

S: "By your lungs I guess."

I: "Where are our lungs?"

S: "Around the heart."

I: "What parts of the body need air?"

S: "The lungs - all the parts of the body I guess, because it gets into the lungs and the blood carries the oxygen I guess."

Belief Category 3a.1-B: The air goes to the lungs and the heart. (n=6)

Diane (14:4 - Grade 8)

I: "Where does the air go when you inhale it?"

S: "It goes into your lungs."

I: "Do we need air in order to live?"

S: "Yes, your heart needs air - oxygen."

I: "What does the heart do with the air or oxygen?"

S: "Your heart goes this way (subject indicates pumping action with fist) when you inhale and exhale. Your heart does the same thing. So it inhales and exhales oxygen."

I: "Does the heart pump this oxygen?"

S: "Yes, like into your lungs when you exhale, and when you inhale it goes through your lungs and into your heart. It keeps your heart pumping."

Julie (9:8 - Grade 4)

I: "Where does the air go in your body?"

S: "Into your lungs" (points to chest).

I: (later) "What parts of your body need air in order to live?"

S: "Your lungs and your heart."

I: "How does the air get from your lungs to your heart?"

S: "There is this one part of your body that goes from your throat down to your lungs and your heart."

I: "Does our heart have anything to do with our breathing?"

S: "I think as well as pumping the blood, I think it might sort of push the air out of your body and then out of your mouth so you can breathe. The heart is beating and it pumps the air out like it pumps the blood."

Belief Category 3a.1-C: The air goes into the heart. (n=7)

Mark (12:4 - Grade 6)

I: "Where does the air go when we breathe it in?"

S: "Into our heart."

I: "What happens to the air once it's in your heart?"

S: "You breathe it out, because you need fresh air in your heart."

I: "What happens to the air once it's inside our bodies? Once it goes in, what happens to it?"

S: "It helps our blood move and keeps it fresh."

I: "Do any other parts of the body need air?"

S: "No"

I: "Does the heart have anything to do with our breathing?"

S: "We need fresh air in our heart, and when we breathe it out, that means that we have bad air in our heart."

Belief Category 3a.1-D: The air goes to the stomach (with the food) and also to the legs.(n=1)

Margaret (7:10-Grade 2)

I: "What part of your body does the air go to?"

S: "It goes to your stomach and your legs."

I: "How does it get down to your stomach and your legs?"

S: "By bones pushing it down."

I: "What parts of your body need air?"

S: "Your legs and your tummy."

I: "How does the air get down to our legs and our tummy?"

S: "It blows down."

Comments About Subquestion 3a.1 - Where does the air go when we inhale it?

Twenty-four subjects, primarily from grades 4, 6,

and 8, believed that the air, when it is inhaled, travels to the lungs. Six of these further suggested that the air travels from the lungs to the heart. Four of these six subjects thought that the pumping action of the heart is responsible for the movement of the air through the lungs during inhalation and exhalation.

Seven subjects, primarily from grade 2, believed that the air travelled directly to the heart. This group was then further divided into three groups: one thought that the air mixes with the blood at the heart, another group thought that the heart pumps this air throughout the body in tubes, and a third group believed that the air is inhaled and exhaled by the pumping of the heart (in this case the air only travels to the heart and out again).

One subject from grade 2 believed that the air goes only to the stomach.

TABLE SEVEN

Major Question 3a: How is the blood related to the respiratory system?

Subquestion 3a.1: Where does the air go when we inhale it?

Belief Categories:

3a.1-A: The air goes to the lungs in the chest.
3a.1-B: The air goes to the lungs and the heart.
3a.1-C: The air goes to the heart.
3a.1-D: The air goes to the stomach (with the food) and also to the legs.

	CATEGORY			
GRADE	3a.1-A	3a.1-B	3a.1-C	3a.1-D
2	3	-	4	1
4	5	2	1	-
6	5	1	2	-
8	5	3	-	-
Females	9	4	2	1
Males	9	2	5	-
2F	2	-	1	1
2M	1	-	3	-
4F	2	2	-	-
4M	3	-	1	-
6F	3	-	1	-
6M	2	1	1	-
8F	2	2	-	-
8M	3	1	-	-

8) Major Question 3a: How is the blood related to the resiratory system? (I23-I29)

Subquestion 3a.2: Is the air distributed to other parts of the body, and if so, how is it distributed? (I27-I29)

Total Belief Categories for Subquestion 3a.2

3a.2-A: The air travels to the lungs. The blood from the heart mixes with this air at the lungs. This blood then travels to the heart where it it pumped to other parts of the body. (n=8)

3a.2-B: The air travels to the heart. The heart then pumps this air through "tubes" or "vessels" to other parts of the body. (air and blood are separate) (n=3)

3a.2-C: The air travels to the lungs and the heart.The heart then pumps this air through "tubes" to other parts of the body. (Air and blood are separate) Air is also absorbed through the skin.(n=1)

3a.2-D: The air travels to the heart. The air mixes with the blood there and it is pumped by the heart to other parts of the body. (n=4)

3a.2-E: The air travels to the lungs. From here it flows through "tubes" or "vessels" to different parts of the body. (n=2)

3a.2-F: Air is distributed to the stomach and legs. It is "blown" down by the bones. (n=1)

3a.2-G: The air travels only to the lungs and the heart. The heart then "pumps" the air out of the mouth during exhalation. (n=3)

3a.2-H: The air travels only to the lungs. It is then exhaled back through the mouth. (n=7)

3a.2-I: Air is distributed to other parts of the body. No suggestions as to how it is distributed. (n=3)

Exemplary Interview Exerpts Corresponding to Belief Categories (SQ.3a)

Belief Category 3a.2-A: The air travels to the lungs. The blood from the heart mixes with this air at the lungs. This blood then travels to

the heart where it is pumped to other parts of the body. (n=8)

Brenda (11:5 - Grade 6)

S: "I think that when we breathe air, it brings oxygen to our heart."

I: "Can you tell me a bit more about that?"

S: "When we breathe oxygen, it goes to our heart."

I: "How does the oxygen go to the heart?"

S: "Through our lungs."

I: (subject had previously indicated that the fingers needed air) "How does the air get to our fingers?"

S: "Through the heart, in the blood."

I: "What parts of the body need air in order to live?"

S: "Well I guess all of them do."

I: "How does the air get to all the different parts?"

S: "Through the veins and the blood."

Calvin (11:5 - Grade 6)

I: "When you breathe, where does the air go?"

S: "It goes into your lungs and it goes into the blood at the lungs."

I: "How does it get into your blood at the lungs?"

S: "Well I think there is veins there where the air travels into the blood, and it's sort of like an intersection and it gets into the blood there "

I: "What parts of the body need air in order to live?"

S: "The brain and the heart and almost every part."

I: "How does it get to these parts?"

S: "By when you breathe and then it gets into the blood and then the heart pumps it to all the different parts."

Belief Category 3a.2-B: The air travels to the heart. The heart then pumps this air through "tubes" or "vessels" to the other parts of the

body. (air and blood are separate) (n=3)

Neil (10:2 - Grade 4)

I: "Are there any other parts of the body that need air?"

S: "The head. (later) When the heart is beating, the air is just circling around in the chest."

I: "You were saying that the head needed air. How does the head get the air?"

S: "Some of the air sometimes travels through your neck and into your face."

I: "How does it get to your brain?"

S: "It just floats up in the back of your neck and stays there."

I: "Can you tell me a bit about how the heart works?"

S: "Well, like the heart pump is beating and the air is just moving around and some of the air comes up into your neck and into your face and when you breathe again I think the old air comes out of your brain and out of your nostrils."

I: "What does this have to do with the heart?"

S: "Well like the heart is beating and it travels some of the air up here." (points to head)

I: "What does it do with the air?"

S: "Well it blows the air up a little here."

Jack (7:5 - Grade 2)

S: "The heart, it makes the blood move, and the air it goes into your heart, so it kind of helps it."

I: "What happens to the air once it goes into the heart?"

S: "Then you breathe it out again."

I: (later) "Do any other parts of the body need air?"

S: "I think right there (points to chest) and there (points to abdomen)...(later) and a little to the brain."

I: "How does the air get down to these parts?"

S: "Not all the vessels carry blood, some carry air."

I: "How does the air get to the brain?"

S: "It travels in these things." (points to veins on hand)

I: "But you said blood travelled in these lines."

S: "Not all of them."

Belief Category 3a.2-C: The air travels to the lungs and the heart. The heart then pumps this air through "tubes" to other parts of the body.(air and blood are separate) Air is also absorbed through the skin. (n=1)

Diane (14:4 - Grade8)

I: "What parts of the body need that air?"

S: "Mostly your stomach, I don't know about your arms and legs. They're just with the blood mostly."

I: "How does the air get from your lungs down to your stomach area?"

S: "Through the heart, you know how the heart has a whole bunch of tube passages, well it goes all through those veins, and they go all through."

I: "But you said that veins were for blood."

S: "Ya I know, your heart has veins coming from it, right, well they've got tubes in it - but they pump air through you."

I: "So you mean there is some tubes for air and others for blood?"

S: "Veins for blood and tubes for air."

I: "So as far as the other body parts that need air, you think it is just the stomach that needs it."

S: "I don't know whether your arms need it inside, outside they would because your skin absorbs air."

Belief Category 3a.2-D: The air travels to the heart. The air mixes with the blood there and it is pumped by the heart to other parts of the body.

Katie (9:5 - Grade 4)

(Subject had previously indicated that air went to the lungs and the heart)

S: "Like the heart keeps them (air) in, - the lung doesn't sometimes."

I: "The heart keeps what in?"

S: "Air - fresh air, to go in your blood."

I: "What does it do with the blood?"

S: "The air goes into the blood."

I: "Oh I see, can you tell me what happens then?"

S: "It helps the blood go quicker, and sometimes it moisters the blood."

I: "I see, you said "that the air went into the heart."

S: "The heart keeps some air and some air it doesn't keep."

I: "I see and can you tell me how the air is mixed with the blood?"

S: "Well like I was saying before, if you get a cut somewhere, if it's warm air, your blood will bleed warm, and sometimes if it's cold air, your blood will bleed cold air blood."

Belief Category 3a.2-E: The air travels to the lungs. From here it flows through "tubes" or "vessels" to different parts of the body. (n=2)

Kelly (7:6 - Grade 2)

I: "Where does this air go?"

S: (subject points to chest area)

I: (later) "What parts of the body need air?"

S: "Around the heart and a bit to the hands and feet."

I: (later) "How does the air get down to our hands and feet?"

S: "Like whenever you breathe, it quickly goes down to your legs and comes back up slowly."

I: "How does it get from there to there?"

S: "You know like you blow into a pipe, like your throat. It's stuck over here (points to chest and abdomen) and then it comes down (points to legs)."

Belief Category 3a.2-F: Air is distributed to your stomach and legs. It is "blown" down by the bones. (n=1)

Margaret (7:10 - Grade 2)

I: "What part of your body does the air go to?"

S: "It goes to your stomach and your legs."

I: "How does it get to your stomach and your legs?"

S: "By the bones pushing it down."

I: "What parts of your body need air?"

S: "Your legs and your tummy."

I: "How does the air get from our mouth down to our legs and our tummy?"

S: "It blows down by the bones.

Belief Category 3a.2-G: The air travels only to the lungs and the heart. The heart then "pumps" the air out of the mouth during exhalation. (n=3)

Dawn (12:3 - Grade 6)

I: "Where does the air go when it is inside you?"

S: "To the heart."

I: "What parts of the body need air in order to survive?"

S: "The heart, and I don't know what else needs it."

I: "Does the heart have anything to do with breathing?"

S: "When it pumps, then you breathe.You need the heart to pump back and forth so you can breathe."

I: "Pump what back and forth?"

S: "The air."

Belief Category 3a.2-H: The air travels only to the lungs. It is then exhaled back through the mouth (n=7)

Curt (10:1 - Grade 4)

I: (subject has indicated that air travels to the lungs when

we breathe in) "Are there any other parts of the body that need air?"

S: "I don't think so."

I: "Does your heart have anything to do with breathing?"

S: "It pumps and then our lungs pump and we have air... Everytime your heart pumps, your lungs go up and down and then you can breathe."

I: "Does the blood have anything to do with our breathing?"

S: "No, the blood has nothing to do with it."

Comments About Subquestion 3a.2: Is the air distributed to other parts of the body, and if so, how is it distributed?

Two-thirds of the subjects believed that the air is somehow distributed to the entire body. Ten children (beliefs 3a.2-G and 3a.2-H) thought that the air only goes as far as the lungs, or the lungs and the heart, before it is exhaled. These ten subjects represented an even distribution across all four grades.

For those twenty-two subjects that thought that the air goes to the body, there were three broad categories of belief as to how this air is distributed.

The first category believed that the blood is the primary source of air transport. Eight children, four each in grades 6 & 8, suggested that the air mixes with the blood at the lungs, while four others believed that this mixture takes place in the heart. (two from grade 2, and one subject each from grades 4 and 8)

The second category believed that the air is

distributed to the body by way of special "tubes" or "vessels". Thus the air is distributed in the same manner as the blood. In this sense, the tubes are similar in function to the veins. The three origins for these air tubes were the lungs (Belief 3a.2-F,n=2), the heart (Belief 3a.2-B and 3a.2-C, n=4), and the throat (Belief 3a.2-F, n=1). Some subjects labelled these tubes as "veins". However, when they were asked if the air ever touched the blood, they indicated that it did not. This air-tube method of air distribution appeared to be mainly a belief held by the younger subjects (n=4 in grade 2, n=2 in grade 4, and n=1 in grade 8).

Only one child (from grade 8) believed that air can also be absorbed through the pores of the skin.

The third category of subjects (n=3) had no suggestions as to how the air is transported, however they were certain that it is distributed throughout the body.

TABLE EIGHT

Major Question 3a: How is the blood related to the respiratory system?

Subquestion 3a.2: Is the air distributed to other parts of the body, and if so, how is it distributed?

Belief Categories:

3a.2-A: The air travels to the lungs. The blood from the heart mixes with the air at the lungs. This blood then travels to the heart where it is pumped to other parts of the body.

3a.2-B: The air travels to the heart. The heart then pumps this air through "tubes" to other parts of the body. (Air and blood are separate)

3a.2-C: The air travels to the lungs and the heart. The heart then pumps this air through "tubes" to other parts of the body. (Air and blood are separate). Air is also absorbed through the skin.

3a.2-D: The air travels to the heart. This air mixes with the blood here and it is pumped by the heart to other parts of the body.

3a.2-E: The air travels to the lungs. From here it flows through "tubes" or "vessels" to different parts of the body.

3a.2-F: Air is distributed to your stomach and legs. It is "blown" down by the bones.

3a.2-G: The air travels only to the lungs and the heart. The heart then "pumps" the air out of the mouth during exhalation.

3a.2-H: The air travels only to the lungs. It is then exhaled back through the mouth.

3a.2-I: Air is distributed to other parts of the body. No suggestions given as to how it is distributed.

	CATEGORY								
GRADE	3a.2A	3a.2B	3a.2C	3a.2D	3a.2E	3a.2F	3a.2G	3a.2H	3a.2I
2	-	2	-	2	1	1	-	2	-
4	-	1	-	1	1	-	1	3	1
6	4	-	-	-	-	-	2	1	1
8	4	-	1	1	-	-	-	1	1
Females	5	1	1	1	2	1	2	3	-
Males	3	2	-	3	-	-	1	4	3
2F	-	1	-	-	1	1	-	1	-
2M	-	1	-	2	-	-	-	1	-
4F	-	-	-	1	1	-	1	1	-
4M	-	1	-	-	-	-	-	2	1
6F	2	-	-	-	-	-	1	1	-
6M	2	-	-	-	-	-	1	-	1
8F	3	-	1	-	-	-	-	-	-
8M	1	-	-	1	-	-	-	1	1

Comments About Major Question 3a: How is the blood related to the respiratory system?

Twelve subjects believed that the air is distributed throughout the entire body by mixing with the blood. In this sense, the distribution of the blood corrlates to the distribution of the air. These twelve subjects were primarily older children (n=2 in grade 2, n=1 in grade 4, n=4 in grade 6, and n=5 in grade 8). There did not appear to be any obvious differences between the responses of either sex. These subjects who subscribed to this belief can clearly be divided into two groups. Some believed that the air mixes with the blood at the lungs (n=8), while the others believed that this mixture occurs at the heart (n=4). All the "lung mixture" children were from grades 6 and 8 (four in each).

The remaining twenty subjects who were interviewed either didn't think that the air is distributed to the rest of the body, or they conceived of some other means for the air distribution throughout the body.(Three subjects had no ideas as to how it is distributed)

9) Major Question-3b: How is the blood related to the digestive system? (I30-I36)

Total Belief Categories For Major Question 3b

3b-A: The food goes to the stomach. There it gets broken up and dissolves into the blood. This blood is then distributed to the body. (n=14)

3b-B: The food only goes to the stomach. It is not distributed to the rest of the body. (n=2)

3b-C: The food goes to the stomach. From the stomach it passes to the heart. The heart then makes blood from this food.(Blood only touches food in the heart) (n=1)

3b-D: The food only goes to the "tummy". Once in the tummy, the "bad" food is exhaled into the air. The "good" food stays in the tummy. (n=1)

3b-E: The food goes to the stomach. From the stomach, it passes through tubes to the heart. The heart then mixes it with the blood and passes it to the rest of the body. (n=2)

3b-F: The food goes to the stomach. From there it travels to other parts of the body through "tubes" or "vessels". (n=7)

3b-G: The food goes to the stomach. It also travels to other parts of the body. No suggestions given as to how it travels. (n=4)

3b-H: No explanations given as to where the food goes after it is swallowed. (n=1)

Exemplary Interview Excerpts Corresponding to Belief Categories (M.Q.3b)

Belief Category 3b-A: The food goes to the stomach. There it gets broken up and dissolves into the blood. This blood is then distributed to the body. (n=14)

George (11:8 - Grade 6)

I: "Where will the food go after you have swallowed it?"

S: "Into your stomach, and then into your digestive system."

I: "What is your digestive system?"

S: "Well it is just a bunch of coiled tubes. It has acid and stuff in it and it digests all your food. When it is in your digestive system, you get all the nutrients and stuff out of it and then you go to the bathroom."

I: "What does food do for us to keep us alive?"

S: "Well it has got all the nutrients and vitamins and stuff like that, and it goes into our blood."

I: (later) "How does the food get from your digestive system to the rest of the body?"

S: "In your blood."

Belief Category 3b-B: The food only goes to the stomach. It is not distributed to the rest of the body. (n=2)

Dawn (12:3 - Grade 6)

I: "Where does food go after we have swallowed it?"

S: "To your stomach."

I: (later) "What parts of the body need food?"

S: "I just know that the stomach needs food."

Belief Category 3b-C: The food goes to the stomach. From the stomach it passes to the heart. The heart then makes blood from this food. (blood only touches the food in the heart) (n=1)

Katie (9:5 - Grade 4)

I: "Where does the food go after you have swallowed it?"

S: (Subject refers to the abdomen on the human figure)

I: "What does food do to keep us alive?"

S: "It makes more blood."

I: "Does all food make blood?"

S: "The good food but not the rotten food... Ya, and then it digests and then some of it vibrates here, and I think the good part vibrated to the heart, and the heart pushes,- makes it into blood."

I: "How does it get from the stomach to the heart?"

S: "From the stomach to the heart, it vibrates, and it doesn't go through any veins or anything."

I: "OK, and what does the heart do with the food?"

S: "Makes it into blood."

I: "And then what happens?"

S: "Then it goes through some veins."

Belief Category 3b-D: The food only goes to the "tummy". Once

in the tummy, the "bad" food is exhaled into the air. The "good" food stays in the tummy. (n=1)

Brad (7:8 - Grade 2)

I: "Where did the food go after you swallowed it?"

S: "In your tummy."

I: "Where did it go after that?"

S: "Like all the bad stuff that you eat,- it grinds it up and sees what's bad and it throws it out with your air, and the good things that you eat stay in your tummy."

I: "Do you know what parts of the body need food?"

S: "The food can't go anywhere once it's gone in your tummy. If the bad things go with your breathing, they stay out in the air."

I: "Do we see food when we breathe?"

S: "It grinds it up really well."

I: "Does the blood ever touch the food when it is inside us?"

S: "No I don't think so. I think the veins just go over your tummy to somewhere."

Belief Category 3b-E: The food goes to the stomach. From the stomach it passes through tubes to the heart. The heart then mixes it with the blood and passes it to the rest of the body. (n=2)

Harry (14:2 - Grade 8)

I: "When you had breakfast this morning, where did the food go when you swallowed it?"

S: "To the stomach I guess."

I: "What parts of the body need food?"

S: "All parts need food."

I: "How does it get to these parts?"

S: "Through the blood. It is put into the heart and then the heart mixes it with the blood."

I: "Can you tell me a bit more about that?"

S: "It's churned into acids in your stomach, then it somehow goes through some tubes or something to your heart and then the heart takes it and disperses it into the blood and then the blood takes it through the body."

Belief Category 3b-F: The food goes to the stomach. From there it travels to other parts of the body through "tubes" or "vessels". (n=7)

Doug (11:5 - Grade 6)

I: "What parts of the body need food?"

S: "Your arms and your legs and your heart."

I: "How does the food get from your mouth down to your arms and your legs and your heart?"

S: "Most veins pump blood, but some of them bring other things down to your legs and arms to make them stronger...sometimes you have green veins and red veins."

I: "Which are which?"

S: "I think the red ones carry blood and the green veins carry other things like food to make you strong."

I: "Does the blood ever touch the food as it is going around?"

S: "I don't think so."

Lynne (11:7 - Grade 6)

I: "Before, you were telling me that when you swallowed, the food went from your mouth down into your lungs. How does it get from your lungs to your legs?"

S: "Through tubes."

I: "Can you describe these tubes?"

S: "They're not as small as veins. They're not really hard - they're soft, and they carry food to the parts of the body."

I: (later) "Does this blood ever touch the food as it is going through us?"

S: "I don't think so."

Comments About Major Question 3b: How is the blood related to the digestive system?

Twenty-seven subjects believed that the food is distributed throughout the entire body. Sixteen of these subjects thought that the blood is the vehicle which distributes this food. This was a belief which appeared to be predominently held by the older children (n=1 in grade 2, n=3 in grade 4, n=5 in grade 6, and n=7 in grade 8).

There were two main ideas as to where the food mixes with the blood. Most subjects (n=14) suggested that the stomach is the mixing place, while two subjects from grade 8 thought that the food mixed with the blood at the heart.

Seven children from grades 2, 4, and 6, thought that the food is distributed by way of tubes to the rest of the body. This parallels the belief that the air is distributed throughout the body in "air-tubes" (Beliefs 3a.2-B, 3a.2-C,3a.2-E, and 3a.2-F, total n=7).

Only four subjects thought that the air is not distributed throughout the body.

One child (see appendix 2) thought that the food "produces" the blood, but there was no indication of a belief that the food is transported to the rest of the body by way of this blood.

In each case, if the child indicated that the periferal body parts such as the arms, the legs, or the head

needed food, the investigator assumed that the child believed that the "entire body" receives a distribution of this food.

TABLE NINE

Major Question 3b: How is the blood related to the digestive system?

Belief Categories:

3b-A: The food goes to the stomach. There it gets broken up and dissolves into the blood. This blood is then distributed to the body.

3b-B: The food only goes to the stomach. It is not distributed to the rest of the body.

3b-C: The food goes to the stomach. From the stomach is passed to the heart. The heart then makes blood from this food. (Blood only touches the food in the heart).

3b-D: The food only goes to the "tummy". Once in the tummy, the "bad" food is exhaled into the air. The "good" food stays in the tummy.

3b-E: The food goes to the stomach. From the stomach it passes through tubes to the heart. The heart then mixes it with the blood and passes it to the rest of the body.

3b-F: The food goes to the stomach. From here it travels to other parts of the body through "tubes" or "vessels".

3b-G: The food goes to the stomach. It also travels to other parts of the body. No suggestions are given as to how it travels.

3b-H: No suggestions given as to where the food goes after it is swallowed.

	CATEGORY							
GRADE	3b-A	3b-B	3b-C	3b-D	3b-E	3b-F	3b-G	3b-H
2	1	-	-	1	-	2	3	1
4	3	1	1	-	-	3	-	-
6	5	1	-	-	-	2	-	-
8	5	-	-	-	2	-	1	-
Females	6	2	1	-	1	4	2	-
Males	8	-	-	1	1	3	2	1
2F	-	-	-	-	-	2	2	-
2M	1	-	-	1	-	-	1	1
4F	1	1	1	-	-	1	-	-
4M	2	-	-	-	-	2	-	-
6F	2	1	-	-	-	1	-	-
6M	3	-	-	-	-	1	-	-
8F	3	-	-	-	1	-	-	-
8M	2	-	-	-	1	-	1	-

CHAPTER FIVE

CONCLUSIONS, EDUCATIONAL IMPLICATIONS and RECOMMENDATIONS for FUTURE RESEARCH

5.00 Summary of the Study

This study has progressed with two main objectives:

A) to identify, through the use of individualized interviews, the nature of childrens' beliefs about the human circulatory system.

Specifically, these interviews were directed towards uncovering the beliefs about the following three research questions:

1) What are the functions of the heart?

2) What are the paths and methods of blood circulation?

3) What are the functions of the blood?

3a) How is the blood related to the respiratory system?

3b) How is the blood related to the digestive system?

B) to determine any possible trends or patterns in these beliefs which might coincide with the development and/or the sex of children as they are observed from grades two through eight. (ages 7 through 14 years)

Thirty-two subjects from this age category were observed in this study.

The interview data were analyzed so as to produce a "conceptual inventory" for each research question. These collections of beliefs were then categorized and further examined in order to show the presence of any trends which might correspond to the age or the sex of the children.

5.10 Conclusions of the Study

Due to the exploratory and descriptive nature of this study, there was no formal testing of research hypotheses. However, conclusions can be made about the methodology which was employed in this work, and also about the types of beliefs held by the children in this study.

(1) The methodology used in this study (a modification of Piaget's Clinical Method) was useful for determining the nature of childrens' beliefs about the human circulatory system. This methodology was also useful for comparing these beliefs so as to determine the presence of any trends which might be related to the age and/or sex of the child.

This methodology permitted enough flexibility for the child to elaborate on many of the topics of his or her own interest, yet it maintained enough direction to allow for a comparison of the beliefs between children. The activities which were employed in this study served to facilitate the flow of the discussion and they also provided an alternate perspective for the children to express their views and ideas.

(2) The method of analyzing the results, where a "conceptual inventory" was developed for each research question was an effective means to categorize and thus compare the nature of the children's beliefs about the human circulatory system.

This method allowed for the collapse of a great volume of data into three major research questions and six subquestions. This methodology also permitted a tabular representation of the data so as to offer a quick comparison of childrens' beliefs.

(3) All children aged 7 to 14 years from this study possessed certain beliefs about the human circulatory system. Many of these same beliefs and ideas were held by several other children in the sample.

Thus, it was not uncommon to find similarities in belief between both children of the same age and children of different ages. Also, it was found that there was a great diversity in these beliefs about the human circulatory system.

(4) There were no trends in beliefs about the human circulatory system that were sex-dependent or grade/sex-dependent.

(5) There were several developmental trends which were evident from the data regarding childrens' beliefs about the human circulatory system.

One must be very careful in the interpretation of this conclusion. The investigator is not attempting to match specific beliefs with specific ages, because the same beliefs were found to be present in children across several ages. However, it can be said that certain trends or inclinations do exist, such that "older" children may be more likely to possess one belief, and "younger" children will be more likely to possess other beliefs. In this sense, it may be possible to perceive the way that children develop an understanding about a particular concept.

The following conclusions are based on the presence or absence of any developmental trends which exist in the childrens' beliefs about each of the three major research questions in this study.

(5A) There were no major developmental trends which were evident in the data regarding childrens' beliefs about the functions of the heart.

Most subjects believed that the heart "pumped" or "pushed" the blood throughout the body. However several subjects also believed

that the air, when inhaled, travels to the heart. These children can be further divided into three groups according to this belief.

group 1) The heart mixes the air with the blood and pumps this mixture throughout the body. This belief was present at all grade levels.

group 2) The heart pumps the air to the body through separate passages. The heart also pumps the blood throughout the body. Thus the air and the blood are not mixed, this was most prominent in the younger grades.

group 3) The pumping of the heart draws in air during inhalation and pushes the air out during exhalation. The heart also pumps blood to the body. The air and the blood are not mixed. This belief was held by subjects at all four grade levels.

(5B) There were developmental trends evident in the data regarding childrens' beliefs about the paths and methods of blood circulation.

Although this research question was addressed through four "subquestions" there were some definite trends in belief which can be attributed to the relative age of the children interviewed in this study.

The subjects who conceived the pulse as being caused by the blood flowing through the blood vessels were primarily from grades

6 and 8. The younger children (grades 2 and 4) were divided in their beliefs as to what causes the movement of the pulse. These alternate ideas included believing that the pulse is caused by: (a) breathing, (b) brain activity, and (c), the movement of the heart.

There appeared to be some definite developmental trends in the childrens' beliefs about the paths of blood distribution throughout the body. The students who conceived a "circulation" of blood throughout the body were mainly from grades 4, 6, and 8.

There were two principal beliefs as to how the blood circulated in the body. The first idea was that the blood flows in a continuous fashion from the heart to all other parts of the body before returning again to the heart for re-circulation. This belief was predominantly held by the grade 8 children.

The second idea of blood circulation was that the blood flows from the heart to one part of the body and directly back to the heart.

The "non-circulation" beliefs from the grade 2 subjects included the idea that the blood moves in a haphazard fashion as a result of the movements of the body. Other beliefs included suggestions that the blood flows only from the heart towards one part of the body. In this case there was no indication of the return blood-flow back to the heart.

A third category of belief was not correlated to the age of the children. This was typical of subjects from grades 2 and 6. These children thought that the blood flows from the heart to a single

part of the body by moving back-and-forth in a single blood vessel. In this sense, these children do conceive of the circulation of blood as being to and from the heart.

The childrens' beliefs about the functions of the veins did not appear to fall into any distinct developmental patterns. Most subjects from all grades thought that the function of the veins was to allow blood movement. Another idea about the function of these structures was that they served to connect and thereby support the different parts of the body.

There was also an absence of any developmental trends in the childrens' beliefs about the orgin of the blood. Most thought that this substance was produced in the heart. Other ideas for this production site for the blood included: the head, the bone marrow, the stomach, and from the pre-natal maternal source.

(5C) There were developmental trends evident in the data regarding childrens' beliefs about the functions of the blood.

The children who thought that the blood carries food and air to the body were predominently from grades 6 and 8. The same trend was true for the subjects who thought that the blood carried only food throughout the body. These children were mainly from grades 4, 6, and 8.

By and large, the younger children from grade 2 had no ideas about the functions of the blood.

(5D) There were developmental trends evident from the data regarding childrens' beliefs about how the blood is related to the respiratory system.

The belief that the air is distributed throughout the body by mixing with the blood was generally held by the older students in grades 6 and 8. These subjects can be further divided into two groups. Some believed that the air mixes with the blood at the heart. Other children believed that this mixture takes place at the site of the lungs.

Several of the younger subjects in grades 2 and 4 thought that the air, when inhaled, is not at all related to the blood system. In this sense, the air goes only to the lungs, where it is subsquently exhaled out of the body.

Another idea which was typical of the younger grade 2 and 4 children, was that the air was pumped throughout the body by the heart. This air-flow was thought to occur through "tubes" or "vessels", which are similar in function to the veins.

(5E) There were developmental trends evident in the data regarding childrens' beliefs about how the blood is related to the digestive system.

Most of the older children from grade 6 and 8 believed that the food is distributed throughout the body through the blood stream. Many of these children thought that this food mixes into the blood at the stomach, however a few suggested that the food travels through tubes to the heart before it is mixed into the blood system.

The younger children in grades 2 and 4 were divided in their beliefs. Some thought that the food is distributed to the body through special "tubes" or "vessels", while others had no ideas as

to how the food is distributed.

(6) There were many parallels in beliefs about the heart and the circulatory system between the children of this study and the ancient philosophers and scientists.

If we assume that the everyday experiences of children play a part in guiding the development of their conceptual theories and ideas, then it is not surprising that we find several similarities in belief between the young child and the early philosophers and scientists who have lived at a time when these same every-day experiences were commonplace.

The data from this study reveal strong resemblences to the early historical concepts which are recorded in the literature. Some of these similarities are listed below:

A) The Egyptians (3000 B.C.) believed that the blood is synonymous with life - without blood there is no life.

B) Hippocrates (460-370 B.C.) believed that the air which is inhaled, travels from the lungs to the heart. From the heart, the air was thought to distribute throughout the body through the arteries. The veins, however, were thought to be the only vessels which carry the blood. In this sense, the air did not come in contact with the blood.

C) Aristotle (384-322 B.C.) was the first to suggest that the heart is the bodily source of heat. This was later supported by Galen (138-201 A.D.), who suggested that one function of breathing is to cool the "eternal furnace" which is the heart.

D) Galen further suggested that the blood moves in an ebb and flow movement through the veins. This early theologian hypothesized that air, when inhaled, travels from the lungs to the heart, where it becomes the "vital spirit" by combining with the blood. This vital spirit was then thought to be distributed to the rest of the body. The air or "pneuma" could also enter the arteries through the surface of the skin.

5.2 Educational Implications

Earlier in this thesis, it was suggested that the knowledge of typical children's beliefs about a specific topic could enhance the overall effectiveness of the educational system. Thus, by understanding the nature of these intuitive ideas, it may be possible for educators to take children along a step-by-step path from their pre-existing ideas to the acquisition of desired conceptual outcomes. This may allow these children to disprove any pre-existing "misconceptions" as well as to affirm the accepted viewpoint.

It is the opinion of the investigator that children should learn about their body at as early an age as possible. Thus, it becomes increasingly important for both the teacher and the curriculum developer to become aware of the many ideas that children bring to the classroom so that they may offer the appropriate instructional stratagies so as to direct these children along desired lines of learning.

Educators would benefit from the knowledge of these beliefs by having a better interpretive understanding when presenting these concepts, and also by being able to select appropriate curricula for their students.

Although there is a lack of a core health curriculum in the British Columbia elementary school system, it is apparent that young children have many varied ideas and explanations to account for the internal processes of their body. Consequently, the author feels that such a health curriculum should be introduced into the

school system at an age when children begin to form these beliefs about their body. The results from this study would suggest that grade 2 would be an appropriate level for such an introduction.

It is hoped that the beliefs uncovered in this study will serve to provide an example of some of the typical beliefs that children aged 7-14 years possess. Hopefully in the future, some of these beliefs and ideas will be used by teachers, or they may be incorporated into a psychologically-based curriculum such as recommended by Byrne and Rothman (1979).

5.3 Recommendations for Further Research

On the basis of the research conducted in this study, it is apparent that further investigations of childrens beliefs about the human circulatory system are necessary. The following are the recommendations for this future research:

1) In order to increase the validity of the methodology used in this study, it is recommended that the belief summaries for similar future research be submitted to several people for their evaluation of the findings. Thus the interpretations of future interviews would reflect a consensus of opinion from several investigators. Another method which would increase the validity of these studies would be to administer objective paper-and-pencil tests in order to reconfirm the broad categories of belief as uncovered in the research.

2) As a means of increasing the external validity or generalizabilty of this study, it is recommended that similar research be conducted with a larger sample size. Such research could also determine, through various controlled experiments, the effects of such factors as: socioeconomic background, or previous instruction. This latter suggestion would certainly reveal the degree to which the child's beliefs about the human circulatory system are "amazingly tenacious ad resistant to change" as suggested by Ausubel (1968).

3) Similar research should be conducted to determine the nature of childrens beliefs about other related concepts such as the processes of: digestion, respiration, nervous activity, or reproduction.

4) Teaching stratagies which are based on the beliefs uncovered from this study should be developed in the future. These would form "Phase Three" of Erickson's (1981) scheme for developing teaching stratagies which are based on students' intuitive beliefs.

5) Develop research which explores the origins of childrens' intuitive beliefs about the human circulatory system. By ascertaining these origins, this will give a broader picture of the developmental trends in childrens ideas about this science concept.

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APPENDIX ONE

Letter of Parental/Guardian Consent

University of British Columbia,
Faculty of Education,
Vancouver, B.C., Canada
V6T 1Z5.

Dear Parent/Guardian:

Your child is being invited to participate in a study which deals with the students beliefs about certain science concepts. This study will form the basis of a masters thesis of a U.B.C. student. I feel this study is very important as it will help us to develop science materials and programmes that take into account the ideas and problems expressed by typical children.

Your child's participation will involve an interview of approximately 20-25 minutes and it will consist of asking some questions about a few simple science concepts. We have found in previous work of this kind that the children enjoy and are stimulated by these interviews. The interview will be tape-recorded for later transcription but these will not be released, nor will your child's name even be attached to it as fictitious first names will be used.

If you have any questions at all about this study I would be pleased to discuss them with you. You can reach me during the day at my U.B.C. office (228-6573), or in the evenings at my home number (261-6101).

Your child's participation in this study is totally voluntary and of course he/she can withdraw at any time that he/she (or you) desires. Thank-you for your consideration of this request.

Sincerely yours,

Gaalen L. Erickson
Assistant Professor
Dept. of Math and
Science Education.

Robin Catherall
Masters Student

.....

..... Yes, I would approve of my child taking part in the study.

..... No, I would not like my child to take part in the study.

..... I would like you to contact me to provide more information about the study.

Signature.....

APPENDIX TWO

Exemplary Transcript From A Student Interview

Subject: Katie M.
Grade 4
9 years, five months old.
Grade 4.
Birthdate: Dec. 27, 1971.
Female.

S=Subject I=Interviewer

I: Katie, I'm interested in your ideas on how you think the body works. There's no right or wrong answers to any of the questions I'm going to ask you. Just tell me your own ideas on how you think things work. O.K.? Have you ever seen a tape recorder before?

S: Ya, lots of times.

I: Would you mind if I recorded this conversation?

S: O.K.

I: That's great. You're free to stop at any time you like. (pause) Katie, have you ever heard of the heart before?

S: Ya.

I: What I'd like you to do is to draw a picture for me of a heart on the human figure on this page, and, if you could show me the position of the heart on this figure and also the size and the shape of the heart on this figure.

S: I've got to remember how it was, because I've got an encyclopedia with a human heart in it, and I've got to remember what it looks like. (pause) I think that's how it looks like. Something like that. (refer to Appendix 3)

I: O.K., that's great. Katie, have you ever seen a stethoscope before?

S: Nope. I haven't even heard of one.

I: Well, doctors use these and they put them up to their ears and they listen to what's going on inside our bodies. So how would you like to put this on yourself, put it on your ears....If you'd like to place that against your chest where you think your heart is. You'll have to listen very, very carefully.

S: I can hear it.

I: What do you think that is?

S: Your heart pumping blood.

I: You think it is your heart doing what?

S: Pumping blood.

I: What do you think the heart does, Katie?

S: Well like it, you get, it pumps some blood from your body all over your body, and keeps your body working, and sends messages to your brain and all that.

I: Ah huh. What sort of messages does it send to your brain?

S: I don't know, I'll have to think.

I: You say it pumps blood around your body.

S: Ya.

I: Could you tell me a little more about that?

S: Well, if you get a cut, like, it pumps your blood from your veins and if you get a cut and it's deep, it cuts your vessels or veins, it'll start to bleed.

I: I see. Katie, have you ever heard of the term "pulse".

S: Ya.

I: What's a pulse?

S: Well sometimes if you go like that you can feel your heart beating.

I: Have you ever felt your pulse under your chin?

S: Nope.

I: Put your hand right there under your ear, and under the bottom of your jaw, there.....Can you feel anything moving?

S: It's a pulse.

I: What do you think is causing that movement?

S: The vibration.

S: The heart from the pumping.

I: What is it that you are feeling?

S: I don't know.

I: Do you have any ideas? Remember, there's no right or wrong answers here.

S: No (laughter).

I: You don't know what's causing that movement?

S: Nope.

I: Alright. What would happen, Katie, if you were to get a deep cut on the end of your finger?

S: It would bleed like anything and you'll have to have a bandage.

I: And what would happen if you were cut anywhere else on your body?

S: If it's not too deep, then you won't need a bandage.

I: We're talking about a deep cut.

S: Ya, it could get infected.

I: What else would happen if you were to get cut somewhere else on your body?

S: Well, you might get infected and it might be so bad you'd have to go into hospital or somewhere to get stitches.

I: Ah huh, would a person bleed?

S: Yup.

I: Why would they bleed if they were cut anywhere else on the body?

S: Because it would get into their vein, and the vein would be opened, and they'd start to bleed through the opening.

I: Is this blood all through our bodies?

S: There's blood all through our bodies and muscles and all that.

I: Humm - everywhere in our bodies?

S: Practically, ya, and bones.

I: I see, I see, how does the blood get to these places

in our bodies?

S: By the heart.

I: Well, you said the heart is up in the chest.

S: Ya, like there's pipes joined to the heart and the heart pumps blood in every pipe.

I: I see, and where do these pipes go in the body?

S: Well some go to your legs, toes, go all over your body.

I: I see, and is the blood in the body moving or is it sitting still?

S: Moving.

I: Is it moving all the time?

S: Yup.

I: I see, and what causes the blood to move in our bodies?

S: Well, like everytime the heart pumps more blood, it has to push it down more and the heart pumps practically every second.

I: Does the heart push blood up?

S: Well I don't know. I think so.

I: O.K., could you describe for me, Katie, the path that a little bit of blood might take when it's circulating around, when it's moving around the man in the drawing...What I'll do is give you a fresh sheet of paper, and if you could draw for me the path that a little bit of blood might take. (Subject draws on figure). Could you tell me what's happening here in your drawing? (refer to Appendix 4)

S: Well the blood is going down here, and some's going up there and going around because they have...

I: Where is this point where it's going in the different directions...here, where it is starting?

S: Well ah, here's how it starts, and sometimes it goes upwards and ah...

I: From where? What's this point here?

S: That's from your heart pumping blood.

I: O.K., so that's the heart right there, and it goes, sorry... Can you show me again which direction the blood goes, say in the arm here?

S: It goes upwards through the fingers and also it goes downwards.

I: What's this line here?

S: That's the other side of the vein.

I: I don't know what you mean by one side and the other side.

S: Like, say here's one side of the vein and then you go for the other part - so there's two sides.

I: Oh, I see. This whole thing here is one big vein, is it?

S: Ya.

I: Well, so the heart's continually pushing this blood to the hand, is it?

S: Ya, pumps everywhere.

I: I see. If that was the case, wouldn't the hand build up pressure?

S: (laughter) Sometimes, and sometimes not. Like, if you get string, and tie it around your finger and it gets up to the top part right there, it'll start to get real pressure, and start to sting awhile.

I: I see. Katie, if we were cut with a sharp piece of glass on our wrists or on our necks, would we bleed the same amount as if we were cut on the end of our finger?

S: Probably not.

I: Where would we bleed more?

S: Well, we might bleed on our fingers or our knees or on our legs or on our arms more.

I: Do you know why that is?

S: Because there's so many veins.

I: Where?

S: On our legs and arms.

I: But we're talking about getting cut on our wrists as

opposed to our finger tip. Where would you bleed more? You say you'd bleed more on your finger tip?

S: Ya.

I: But why? Why is that?

S: Well there is so many veins down there and if you get cut more blood will pass through and get opening.

I: I see. O.K. You were saying Katie in your little diagram here that the heart pushes this blood to the different parts of the body (points to diagram).

S: Ya.

I: Where do we get blood in our body?

S: From the food.

I: I see. From the food, eh? Is the blood made in the body from the food we eat?

S: Not always. Sometimes from the air or something.

I: I see. Can you tell me a bit more about how the blood is made from the air.

S: Well some, like when you eat the food and breathe in air, that mixes and sometimes the air is cold, and when you bleed the blood is sometimes cold.

I: I see.

S: Or else the air is warm and the blood is warm.

I: We'll talk a little more about that in a little while. Is there any other spot in the body where we make blood or where we get blood?

S: Maybe around here somewhere. (Subject points to diagram).

I: And what's that? Your pointing to the middle of the man there. Not in his chest, but in his tummy area.

S: Well that's where his food digests.

I: Oh I see. alright....Can I just see the top of your hand Katie? See these blue lines?

S: Those are the veins.

I: And why do we have these veins in our body?

S: To pass blood to the whole body.

I: Ah huh, and where do these veins go in the body?

S: Well, like some go to your head, -everywhere in your body.

I: I see, and do they all start and end somewhere in the body?

S: I don't know that (laughter).

I: Can you take a guess, or if you think about it?

S: Probably.

I: Can you suggest where they might start and where they might end in the body?

S: In your hands and in your feet.

I: And where would they start?

S: From the heart.

I: Do all veins start in the heart?

S: Yup. Or some pass on from other ones.

I: Alright. What direction, or which way does the blood move in those veins?

S: Some go down and some go up.

I: I'm not sure what you mean by that.

S: Like, some blood goes up so that it'll get to your shoulders and all that, and some goes down so it will get to your feet.

I: I see, O.K.. In the vein on your hand here, which direction is the blood moving?

S: Up.

I: It's moving this way, up? (Points up toward's subject's shoulder).

S: I mean down.

I: O.K.. It's moving down towards your finger tips is it?

S: Yup.

I: O.K., that's fine. Are these veins all the same size, or these "tubes" that the blood flows in?

S: Nope.

I: Where would we find the biggest ones, and where would we find the smallest ones?

S: Well, the biggest ones would be along here (points to thigh).

I: On your thigh?

S: Ya.

I: Why is that?

S: Well that's where the biggest bones are, and they come near the bones they use.

I: I see. Do you have big veins near your backbone?

S: I don't know that. It's a hard one.

I: Do you think you'd have big veins in this area (points to the torso), because that's a pretty big area - in your tummy and on your chest?

S: I don't think so, because it could get in the way of the food coming down.

I: I see. Katie, have you ever heard of a heart attack?

S: Ya.

I: What happens to someone when they have a heart attack?

S: Well they fall down and their heart stops pumping.

I: Ah huh, and does anything else happen when their heart stops pumping?

S: Sometimes they lose their oxygen and sometimes they die.

I: Why does someone die when their heart stops beating?

S: Because it's hard to get it back going again, and they'll run out of air, and they'll just die. The blood won't get through to everywhere.

I: Well what does the blood do for the body?

S: It keeps it going.

I: Why do we have blood in us?

S: I don't know. It might keep the body running as well

as the heart.

I: Do you know how it keeps the body going?

S: It can make you move your fingers and all that.

I: Do you know how it makes our fingers move and our body move?

S: Because the veins bend sometimes, and they have lines.

I: I see. Katie, what does every part of the body need in order to live?

S: Well. there's bones and veins.

I: Alright, bones and veins, can you think of anything else?

S: Not really, a heart, a pulse.

I: You were talking a little while ago when we were talking about the heart attack, that the man can't breathe when he dies.

S: Right.

I: What I'd like you to do Katie is a little experiment. When you were young I'm sure you have blown up a paper bag and exploded it (subject agrees). Well, what I'd like you to do is to blow up this paper bag, and then just breathe into it normally.

S: Just blow it up and then breathe into it.

I: Yes, just watch the bag as you breathe into it, O.K.?

S: Does this have a hole?

I: No, no hole. (Subject blows up bag). Now, what's happening to the bag when you are breathing?

S: Well the lungs start to move up and down in me, and the air comes out more.

I: And where does the air go when we breathe?

S: Out into the air, and then we breathe in fresh air.

I: Where does the fresh air go when you breathe it in?

S: Nose.

I: Ah huh, and where else in your body? Where does it go once it's in your nose?

S: Down through your, one of those tubes down there.

I: And once it goes there, where does it go?

S: Down one of the tubes, and then somewhere else in your body, to the lungs I think.

I: Where abouts are the lungs in your body?

S: Right along here, and here.

I: You're pointing to your chest there. Is that the only place where the air goes in the body?

S: To the heart.

I: What does the heart do with the air when it gets it?

S: It pumps it out; some they pump out so they can breathe it out.

I: I see. So the heart...Can you tell me what happens when you breathe in and then describe how the heart fits in, and how the lungs fit in?

S: Well, some go down to your heart and some go down to your lungs, and then you breathe some out of your heart and some out of your lungs, and so on.

I: Well, is your heart beating all the time?

S: Yup, unless you have a heart attack.

I: I see, and when does it push the air out?

S: When you're talking, when you're breathing out.

I: I see, well you told me a little earlier that the heart pumped blood.

S: Some they pump out, and some they pump, some they keep in.

I: I'm sorry I don't understand what you mean.

S: Like, the heart keeps them in, the lung doesn't sometimes.

I: The heart keeps what in?

S: Air - fresh air, to go in your blood.

I: What does it do with the blood.

S: The air goes into the blood.

I: Oh I see, can you tell me what happens then?

S: Then, sometimes that helps it go down more or moistens.

I: Sometimes the air in the blood helps what?

S: It helps the blood go quicker, and sometimes it moistens the blood.

I: I see, you said "that the air went into the heart".

S: Some they keep and some they don't.

I: Some what keeps?

S: Some the heart keeps. The heart keeps some air and some air it doesn't keep.

I: You said the heart pushed the air out of the body.

S: Sometimes it does, like, some goes out of your mouth or nose, and some stays in.

I: I see, and can you tell me how the air is mixed with the blood?

S: Well, like I was saying before, if you get a cut somewhere, if it's warm air, your blood will bleed warm, and sometimes if it's cold air, your blood will bleed cold air blood.

I: I see, and where is this blood with the air in it, pushed around the body?

S: Through the veins, it goes everywhere.

I: Oh, I see. What parts of the body need air in order to live?

S: Hum, well, the lungs, heart - you do, of course. I can't think of anything else.

I: So you think the lungs and the heart are the parts of the body that need air?

S: Yes.

I: Can you give any others.

S: No (laughter).

I: Well how does the air get from the lungs to the heart?

S: Well, not all that goes to the lungs, some goes down

to the heart and some goes into the lungs.

I: I see, through what?

S: I don't know what it goes through, but it goes down inside.

I: Katie, does the heart have anything to do with our breathing?

S: I don't actually know. I think so, because then, sometimes it comes out quicker - if you need faster air.

I: I see, you were saying before that the heart helped to push the air out of us.

S: Ya.

I: Do you think that is what happens?

S: Yup.

I: Katie, when you eat food, where does the food go after you have swallowed it?

S: Down one of your pipes in your throat, and then it digests it and some of the rotten food you have to go to the washroom and take it out.

I: I see, and where does it do this digestion?

S: Well, it makes it settled in, and sometimes you might throw it up.

I: Where does this take place in your body?

S: Mom never told me that.

I: O.K. that's fine. Where do you think it takes place in your body?

S: Right along here (subject refers to figure).

I: You're pointing to the tummy on the man. I see, do we need food in order to live, Katie?

S: Ya.

I: What does food do to keep us alive?

S: It makes more blood.

I: Does all food make blood?

S: The good food, but not the rotten food.

I: Does milk make blood?

S: I think so.

I: O.K.. What parts of the body need food?

S: The whole body.

I: Well, you said that when you swallowed food, it went into your tummy.

S: Ya, and then it digests and then some of it vibrates here, and I think the good part vibrated into the heart, and the heart pushes, and makes it into blood.

I: Oh I see, how does it vibrate to the heart, can you tell me that?

S: Well, like water, it goes up into the air, but in this case it goes into your stomach.

I: How does it get from the stomach to the heart?

S: From the stomach to the heart? It vibrates, and it doesn't go through any veins or anything.

I: Sorry, it what?

S: It doesn't go through any veins or anything.

I: Well I'm not sure how it can vibrate its way to the heart.

S: Like, maybe, it goes through the lungs or something.

I: Ah huh, you think it goes through the lungs.

S: No, not through the lungs, through the knees, bones, right there (points to chest) - the ribs, whatever.

I: I see, so it goes from the tummy through the ribs into the heart?

S: Ya.

I: O.K., and what does the heart do with the food?

S: Makes it into blood.

I: And then what happens?

S: Then it goes through some veins.

I: O.K.,once it's in the veins, where does it go?

S: Through your body.

I: You think then that the blood carries the food through the body?

S: Ya.

I: You were saying earlier that we had blood all through our body. Does the blood ever touch the food when it is in our tummy?

S: No, I don't think so.

I: The blood only touches the food, then, when it is in the heart?

S: Ya.

I: I see, O.K. Katie, one last question and that is have you ever talked about any of these questions in school at all?

S: No.

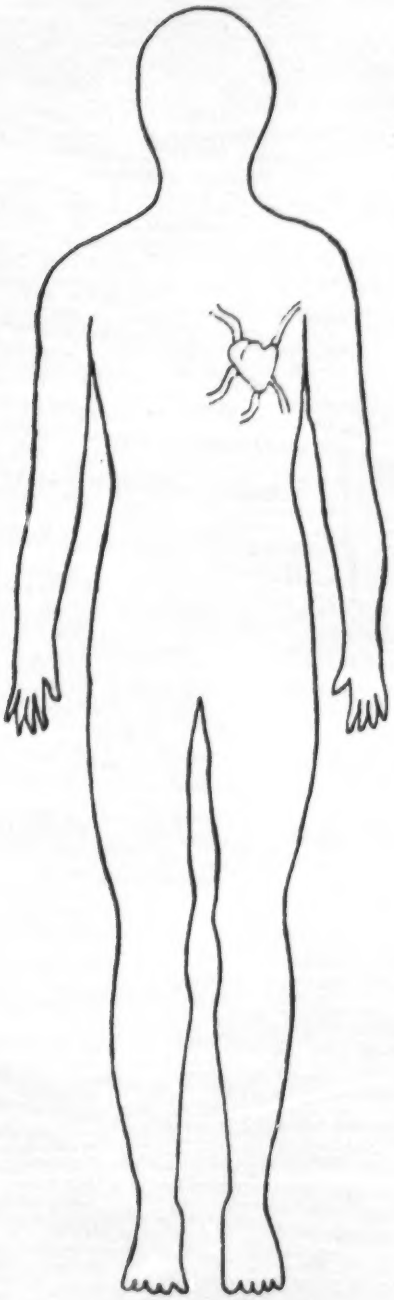
I: You haven't, eh? Alright then, thankyou very much, Katie.

S: O.K..

APPENDIX THREE

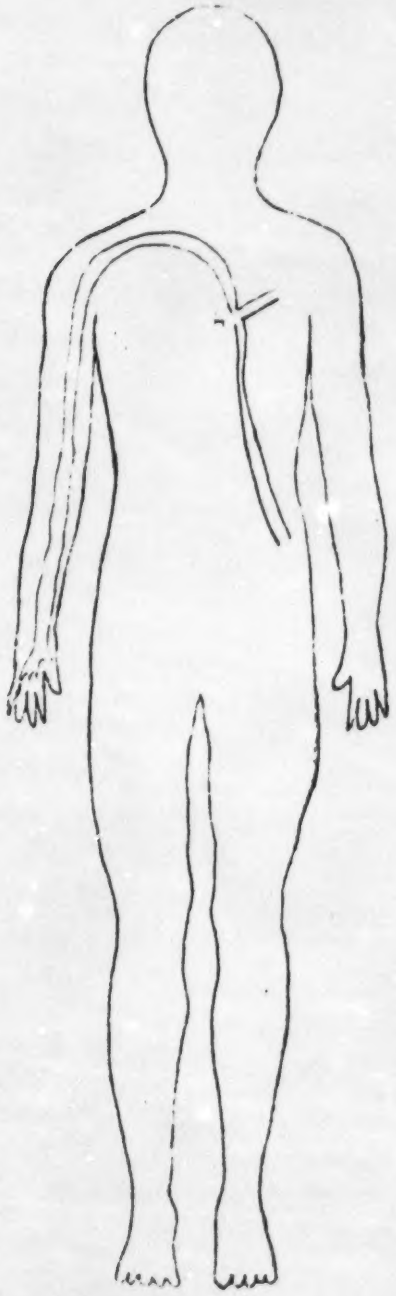
Diagram of the Heart From

the Exemplary Student Interview



APPENDIX FOUR

Diagram of the Human Blood
Circulation From the Exemplary Student Interview



APPENDIX FIVE

Nine Belief Summaries Derived From an Exemplary Student Interview (Katie - Grade 4)

Major Question 1: What is the function of the heart?

Student belief: Air travels to the heart where it is mixed with blood. This mixture is then pumped to the rest of the body. (Belief Category 1-A).

Major Question 2: What are the paths and methods of blood circulation?

Subquestion 2.1: What is the pulse?

Student belief: The pulse is somehow linked with the heart. No further explanations are given. (Belief Category 2.1-A)

Subquestion 2.2: How is the blood distributed throughout the body?

Student belief: From the heart the blood travels through blood vessels. This flow is in one direction only. The blood is only carried by the blood vessels to the body part. No explanations are given as to how it returns to the heart. (Belief Category 2.2-C)

Subquestion 2.3: How do we get blood?

Student belief: Blood is made in the heart. (Belief Category 2.3-A)

Subquestion 2.4: What are the veins and where do they go in the body?

Student belief: Blood flows through the veins. These extend from the heart to the body parts. (Belief Category 2.4-A)

Major Question 3: What are the functions of the blood?

Student belief: Blood carries air throughout the body. (Belief Category 3-D)

Major Question 3a: How is the blood related to the respiratory system?

Subquestion 3a.1: Where does the air go when we inhale it?

Student belief: The air goes to the lungs and the heart. (Belief Category 3a.1-B).

Subquestion 3a.2: Is the air distributed to other parts of the body, and if so, how is it distributed?

Student belief: The air travels to the heart. The air mixes with the blood there and it is pumped by the heart to other parts of the body. (Belief Category 3a.2-D)

Major Question 3b: How is the blood related to the digestive system?

Student belief: The food goes to the stomach. From the stomach it passes to the heart. The heart then makes blood from this food. (Blood only touches the food in the heart). (Belief Category 3b-C)